

The
Sphygmograph.

EDGAR HOLDEN, A.M., M.D.

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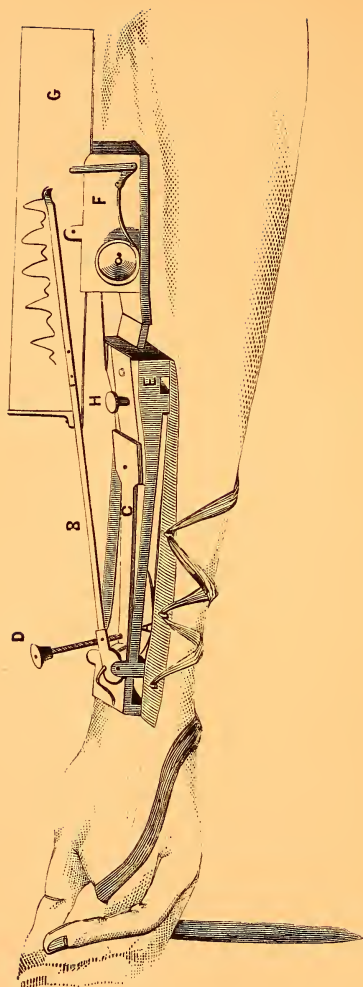
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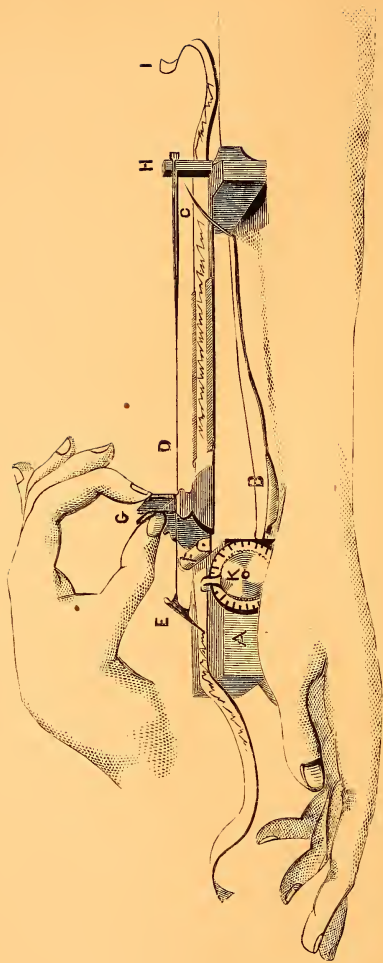


PRIZE ESSAY.



PROF. MAREY'S SPHYGMOGRAPH.

A, the pulse spring; **B**, the tracer, or writing lever; **C**, the lever for transmitting motion from the former to the latter (A to B); **D**, the pressure screw; **E**, the body of the instrument; **F**, the box containing clock-work; **G**, the traveller; **H**, the screw for adjusting pulse spring at a proper obliquity.



DR. HOLDEN'S SPHYGMOGRAPH.

A, the body of the instrument ; **B**, the pulse spring ; **C**, the end of the same bent to an inclined plane ; **D**, the tracer ; **E**, the pen ; **F**, the roller for moving the paper ; **G**, the holder ; **H**, the post for attachment of the tracer ; **I**, the paper for the writing ; **K**, the milled head for regulating the tension of the pulse spring ; also, the dial and brake or stop.



THE
SPHYGMOGRAPH:

ITS PHYSIOLOGICAL AND PATHOLOGICAL INDICATIONS.

THE ESSAY TO WHICH WAS AWARDED THE STEVENS TRIENNIAL PRIZE,
BY THE COLLEGE OF PHYSICIANS AND SURGEONS,
NEW YORK, APRIL, 1873.

Two hundred and ninety Illustrations.

EDGAR HOLDEN, A. M., M. D.

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TO
WM. MAXWELL WOOD, M. D.,

LATE SURGEON GENERAL U. S. NAVY,

IN REMEMBRANCE OF ACTS OF KINDNESS, AND OF ASSOCIATION IN PERIL IN THE
U. S. NAVY, AND WITH THE HOPE THAT THE LABOR BESTOWED IN
PREPARATION MAY JUSTIFY SO CEREMONIOUS AN ACT,
THIS WORK IS INSCRIBED BY

THE AUTHOR.



INTRODUCTORY NOTE.

THE work as here presented has been the result of many months of labor, for the field has been pathless and virtually unexplored ; but it is hoped that it may prove at least a definite and tangible starting point for other observers.

The author desires to state to those who may have read his Essay, published by the State Medical Society of New Jersey, or that delivered before the New York Journal Association, that the views there advanced have been found in some cases erroneous, because drawn from tracings made as with Marey's Instrument, without the means since adopted for accurately determining the compressibility of the artery.

Since then, moreover, the facilities afforded as medical adviser of one of the largest Life Insurance Companies of the United States, and as clinical physician for diseases of the chest to St. Michael's Hospital, have been more liberally drawn upon, that previous opinions might be verified or corrected.

The Essay thus published differs somewhat in form from that presented in competition for the Stevens Prize, but only as regards a certain diffusedness both of tracing and subject matter ; and it is believed that as the tracings particularly have been culled with care, the work has been made only the more serviceable. It may thus be of the more assistance to any who desire to pursue the complex yet interesting study of Sphygmographic hieroglyphics.

The reader is desired not to consider the tracings of cases as the universal and invariable exponents of individual diseases. Such could only be obtained after long and patient investigation into every variety and phase of disease, and is equivalent to making a new symptomatology, a task indeed for a generation of observers. They will, however, probably prove in all cases suggestive of the pathological condition involved.

EDGAR HOLDEN.

NEWARK, N. J., October, 1873.

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THE SPHYGMOGRAPH:

ITS PHYSIOLOGICAL AND PATHOLOGICAL INDICATIONS.

PART I.

CHAPTER I.

GENERAL CONSIDERATIONS REGARDING MECHANISM.

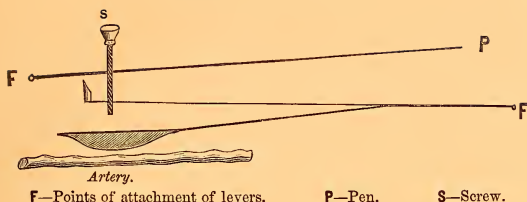
A SPHYGMOGRAPH is an instrument which can automatically record the peculiarities of the arterial pulse. According to Vierordt, to whom we are probably indebted for its suggestion, it was simply "an instrument which, when applied over an artery, indicated its character as to force and extent of undulations," and, as originally constructed, could accomplish this only with difficulty and uncertainty. More recently the ingenious device known as Professor Marey's, showed a wider significance in the sphygmographic tracing, and gave promise of great practical usefulness. It is no disparagement of the invention to say, that the sanguine hopes entertained with

regard to it have not been fully gratified, and that to no inconsiderable extent the disappointment has been due to certain imperfections in the instrument itself. These, however, have arisen mainly from a want of ready applicability, and a tendency to fall out of repair, from the very perfection and refinement of its own mechanism.

As the word Sphygmograph is, to most of those who know of the device, intimately connected with the name of Professor Marey, it is but proper, before presenting results obtained by other means, to allude to the principles, merits and defects of his invention.

This may perhaps be more briefly done by presenting a skeleton diagram of the instrument, or rather endeavoring by an outline drawing, to illustrate its action.

A simple lever, attached at one extremity, rests at the other upon the artery to be examined, and compresses it, therefore, in a vertical direction; a second lever, bent at a right angle and lying directly above this, communicates its motion by a knife edge to a third, and this latter, which is at the same time the tracer, and has upon its free extremity a peculiar pen, amplifies or magnifies the motion communicated. This amplification is simply due to the fact that, as will be seen by the drawing, the motion is directed against the tracer very near its attached extremity.



A screw, near the same point, traverses the tracer and regulates the pressure. The other parts of the instrument, being simply accessories, with perhaps the exception of a concealed watch movement, designed to move the paper to receive the writing, need not be described.

This instrument is strapped to the wrist to insure immobility; and in the hand of its inventor has developed features in the arterial pulse never before discerned. Inasmuch, however, as disappointment has resulted from its subsequent use, and its delicacy and cost have limited the observations which should be manifold, within a narrow scope, it is a fair inquiry whether this disappointment may not after all be due, *not* to a meagre pathological or physiological value of the pulse-wave, but to some defects in the instrument employed.

A glance at these may both answer inquiry and suggest a change.

In the first place, the end of the lever, which may be called the pulse-spring, rests *upon* the artery and

compresses it, as already remarked, in a vertical direction. Thus, as may be seen in the following drawing, any increase of pressure flattens the vessel, and, as will be shown in speaking of amplitude of tracings and arterial tension, a deceptive result is obtained.



The movements of the spring are, as observed by Sanderson, not therefore those of the arterial wall in the fullest sense, and *extent* of motion is inaccurately measured.

As an artery is distended laterally as well as vertically, some of the peculiarities of the contained wave are of necessity lost; especially when the current of blood is small, and the flaccidity of the vessel considerable.

The second defect, as will be conceded by all observers, lies in the method necessary to secure the instrument to the wrist. This is done by straps, or rather a bandage, which hooks in alternate loops over wire pegs on the sides of the instrument, or may be a continuous and single band with straps and buckles. The difficulty of adjustment to the artery, even under favorable circumstances, is considerable; and when the patient is nervous and excited or frenzied by delirium, the tracing obtained after a prolonged trial cannot be accepted as the correct index of the pulsating wave. Indeed, so great is the liability to obtain an

inadequate or erroneous tracing, that many observers have cast the instrument aside, as unworthy the expenditure of time and patience.

Much has, however, been accomplished in the way of remedying this defect by the patient efforts of one to whom much reference must be made in this essay—as having, more than any other, endeavored to render the Sphygmograph of Marey of practical benefit—Professor Burdon Sanderson. Yet, after all, his devices did not perfectly obviate the defect last referred to; and only modified it in so far that the involuntary muscular movements in the wrist of the patient would not impair the tracing.

He adjusted slips of brass to the instrument in such a way that the body of it rested more firmly upon a surface of bone; but an elastic band was made necessary for the retention of this, and this added to what was a much underrated and *additional* defect, viz., obstruction to superficial venous circulation by the retaining straps. To be sure, this obstruction would of necessity be slight, but, in obtaining a record, the nicety of whose indications depends upon such minute particulars, even so slight an obstruction *might* vitiate our results.

To what extent this is actually the case, will be seen by reference to the direct experiments made in this direction, and recorded in this essay.

The third, and, as will be shown by a multitude of observations, vital defect, is the inability to accurately and quickly determine the compressibility of the artery.

By the adjustment of the brass slips referred to, some improvement resulted, inasmuch as, after a series of experiments with various weights, an approximate relation could be arrived at between the distance from the surface of the lever to the spring, and the actual pressure at the time upon the artery.

Other workers adopted various devices to remedy this defect, one only, however, seeming to be a real improvement, viz., that of graduating the screw according to a pre-arranged scale, and thus having at hand an index upon the screw itself. By reference to the drawing, it will, I think, be manifest, that the defect consists in the screw itself, since it bears like an inflexible brake upon the levers with which it is in contact, and when we shall consider this compressibility as one of the most important elements in the arterial current, it will be seen that its ready and accurate record are essential to any real practical usefulness of the instrument.

Recognizing, then, the importance of having as few defects as possible in the device we employ to record the peculiarities of the pulse, and feeling indeed that the question of real moment does not relate to the

practical utility of any given Sphygmograph, nor yet of *the* Sphygmograph, in its best known signification, but to whether there is any deep meaning in the blood current of the accessible arteries, of value in Physiology, Pathology or Therapeutics, which can be accurately ascertained and recorded, I have endeavored to remedy the defects enumerated, as the best method of answering the question in hand.

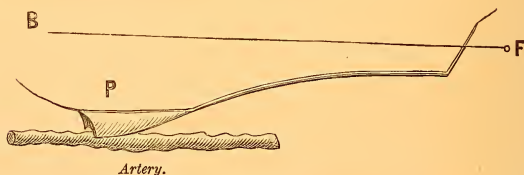
Despairing of any success in the direction taken by the eminent observers of England and the Continent, after their but partial success, it occurred to me that a new principle of construction might accomplish better results. In all instruments thus far adopted the attempt had been made to employ the *lifting* power of the current of blood to obtain a tracing, the difficulties of friction and amplification being the problems to be solved.

The arrangement of the levers and the shape and position of the tracing point, already considered, are probably the most perfect adaptation of mechanism in this direction. (See first Frontispiece.) But instead of attempting to utilize the *lifting*, why not employ the *displacing* power of the artery? Instead of having the spring press *down* upon the artery, let it partially surround it, thus: Then with each pulsation a force is transmitted not only up-



ward, but in an oblique direction, as shown by the dotted lines, the preponderance being toward the side upon which the spring may be inclined. Prolong the pulse spring, and shorten the distance between the point of attachment (the fulcrum) and the point of pressure, and this upward and oblique movement is evident to the eye. To amplify this, allow the free and distal end to be bent as an inclined plane or the curve of a circle; polish it to obviate friction; magnetize it, if desired, to add a repellant power to the power already evident, and allow it to impinge against another lever quite near its attached extremity, (a lever of the third order); make this last flexible, and its distal end will move with regular, accurate sweep under the distensible power transmitted.

The skeleton drawing below will illustrate more perfectly the principle involved.



B—Place for Pen. **P**—Pulse Spring. **F**—Attachment of Flexible Lever, i. e. Tracer.

The movement obtained by this means is from side to side, and not, as in Marey's instrument, in a vertical direction; and in consequence the paper to receive the

tracing may lie as in ordinary writing. (See design on second Frontispiece.) The accessories necessary to the application of this principle need not be described in detail; they are simply a framework of brass; a sliding-post for the attachment of the tracing-lever by which it may be brought in apposition to the inclined plane described; a watch movement for moving the paper to receive the writing; and a means for holding the instrument in the thumb and finger over the artery. The drawing on the second page may render this description more intelligible. Two points, however, of importance, are worthy a moment's notice, viz., the pen, and the means for determining and recording the compressibility of the artery.

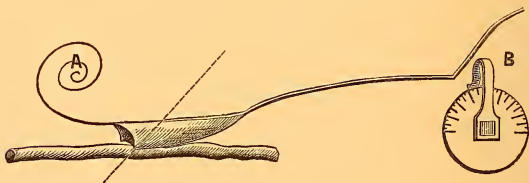
As already stated, the motion obtained is from side to side, and although ample, it is yet so delicate that a hair upon it stops it at once. After many disheartening attempts to utilize chemical re-agents, and the suggestions of various persons of ingenuity, the simple plan of *pivoting* the writing-point—in fact an ordinary pen—and thus making the paper and not the delicate lever carry the weight, solved the problem—thus:



To ascertain with precision the pressure necessary

to obtain an ample tracing, it was evident that no power should be brought to bear upon the pulse, except that of the pulse-spring itself, since relative compressibility could only be accurately determined by variations of the intensity of a common force. The increase or diminution of pressure should therefore be ratios of the ability of the spring itself; in other words, the spring should have within itself the power to press lightly or heavily upon the artery. Its attachment to the body of the instrument was therefore made by a coil of watch-spring, whose tension could be controlled and measured on a dial, at will, an amount of pressure being possible beyond any requirement, and reaching four, five or six pounds.

The drawing illustrates both the coil and the recording dial.



It will be at once evident, that coiling the spring from its centre, A, will bring a pressure just in the very direction most desired, viz., downward and backward against and upon the vessel as indicated by the

dotted line. A curved wire, B, acts both as a brake to prevent the uncoiling of the spring and maintaining it at any desired point, and also as an index for the dial.

As the best and only test for the utility of any invention, is the amount and character of the work it will accomplish, more minute description may perhaps be dispensed with, and reference made to the charts presented in a subsequent part of this essay.

A few words of comment on the extent of pressure sometimes necessary, appear, however, in place at this point.

Most observers, especially Drs. Anstie and J. Burdon Sanderson, have found that a pressure of 100 grammes is the average minimum, and that by the device of the latter a variation of 200 grammes is easily attainable ; this is equivalent to about 3,000 grains. It will be observed on the charts appended, that 700 grammes were often necessary ; and it may be added, that in some cases I have found it possible to obtain a tracing under a pressure of 1,100, or about 17,000 grains.

The dial already described is, as will be seen in the drawing, marked in degrees, the equivalent of each in grains being easily determined by the equipoise of weights upon a balance. The following exhibits the amount of pressure exerted when the spring is coiled

sufficiently to bring the index opposite each degree :

0 °—about 100 grammes, or 1,560 grains.

$2\frac{1}{2}$ ° “ 186 “ 2,880 “

5 ° “ 690 “ 10,620 “

Somewhat singularly, the application of this different principle gives results similar, and therefore readily comparable with those of Professor Marey, and although the celerity and certainty by which the compressibility can be ascertained has often developed features of a pulse-wave that would have been concealed without this, yet the tracings are so nearly akin that they may be explained and treated under the same rules as his own.

Whether the defects that have so nearly wrecked the science of Sphygmography, ere it had well begun its career, have been fully corrected by the means described or not, the reader, who will patiently review the results obtained, will be able to judge.

Two elements, at least, toward the success of the instrument as an aid to science, will, I think, be conceded to the change in its construction, viz., a reduction in cost down to a reasonable and available point,* and a more ready applicability.

Most of the tracings delineated on the charts were

* NOTE.—The instrument used for this work has not become disarranged or out of order after several thousand tracings, and could be duplicated by the maker at a cost of about one-third that of the imported instrument.

OTTO & REYNERS, Inst. Makers, New York.

taken during an ordinary visit, and occupied only from thirty seconds to two minutes; no fastenings were employed, and no preparation necessary, not even in most instances the preliminary rolling-up of the sleeve, save barely to uncover the radial pulse. The instrument was held by the finger and thumb of the left hand, the paper introduced, the ink applied, and the watch-work started by the other. To a great extent, therefore, nervous excitement due to the simple act of examination has not vitiated the tracing, and it is believed that so far as Sphygmographic observations can be the true record of the pulse-waves, these are reliable.

Of the many other devices for ascertaining and recording the peculiarities of the pulse, from the simple column of mercury and the semaphoric registration by the aid of photography, to the attempts to utilize the galvanometer, it is unnecessary to speak; since their failure hitherto to develop better results than their predecessors, has not yet brought them a measureable success. The subject of chief interest is, after all, outside of any particular *method* of observation, and relates to the observations themselves.

We may, perhaps, the better define the true physiological and pathological indications in these by discussing, first, *the actual value of a knowledge of the minute peculiarities of the circulatory current*, and then, *the power of an instrument to develop them*.

CHAPTER II.

INDICATIONS AFFORDED BY THE PULSE.

The pulse, from the earliest record of historic medicine, has been to the Physician a guide and instructor; and, although the elaborate anatomical knowledge of the present day has divested it of the mysterious element so familiar to the student of ancient medicine, and we no longer profess to divine or prophesy by its aid, it is still, in many cases, the key to our patient's condition, and in all a valuable assistant in diagnosis.

Nor can this be due merely to the effect of education, or the example of our predecessors. Every skillful, ambitious physician realizes in daily life that the "tactus eruditus" is to-day as valuable an acquirement as in the days of Galen. We may no longer hide our ignorance under the look of deep and dignified wisdom, or with our fingers on the pulse shake our heads with complacency, while puzzling confusedly over the remedy it would be best to hazard on the case. It is our privilege to have within our reach ample means of information, and neither to over or under-rate the significance of the pulse we feel. To do this, however, it is not sufficient that we be versed in

anatomy or physiology ; for, as we realize to-day that we can read a deeper meaning in its throbbings than a year ago, so each year's experience shows new indications to our more practiced touch, and we feel that without it we should be often in doubt, when doubt might be fatal to our patient. We are wont to regard as absurdities many of the notions of the early physicians, simply because the better facilities of modern times have shown their deductions to have been untenable ; but we overlook the fact that, although shut out from *our* refinement of pathology, they were yet not devoid of wisdom, and, drawing largely from experience, often showed that the homage and respect bestowed upon them were well deserved. We deride the assumption of mystery, although it is fast becoming evident in the present age, that its absence is far from beneficial.

There is, perhaps, no better aid to the success of the charlatan of to-day, than the arrogance grown out of a little knowledge that presumes to weigh for itself questions of disease and treatment. The contempt of familiarity has taken the place of the faith that once helped to cure.

We may be, however, and probably are right in regarding the diffuse nomenclature and labored attempts to make of pulses critical guides to treatment, as not particularly wise, yet in the days of Solano it

is not improbable that they possessed value, crude and imperfect it may be, but value of which we with better information have no knowledge.

This concession can hardly be made, however, to the Chinese of even our own day, by whom the pulse of one wrist is believed to indicate the disease of one organ, that of the axillary artery of another, and who pretend by the femoral pulse of a pregnant woman to determine the sex of her child; yet even in this extreme tax upon credulity there is more of good sense than we are at first inclined to believe; and the fact was strongly suggested during a series of experiments with an artificial heart and system of vessels to which allusion will again be made in this essay. *e.g.*

Upon ligating one of the capillaries in a network of interlacing tubes, the quantity of fluid forced through them remaining the same, very little disturbance or change appeared to have been caused in the others, at least so far as the touch could decide; and yet it was evident that a larger quantity of fluid was compelled to find its way through them than before. A Sphygmograph however, indicated a difference; and when two or more were ligated, a perceptible difference was observed by the fingers. Apply this fact to the human body: suppose, for example, a mass of enlarged lymphatics obstructing the subclavian artery; if this obstruction were slight, the differ-

ence in the feeling of the axillary artery might be perceptible, while the radial, being smaller and more distant, would appear to be unchanged ; or, suppose an engorged liver, or spleen, or hepatized lung, it is by no means irrational to assume that *some* change would occur in even a remote artery. Our experience with the fact that ligating a limb will check an hemoptysis or other hemorrhage exhibits the same fact. Out of similar observations may possibly have grown the whimsical oddities of the Chinese.

What the change in the arterial wave, remote from the source of disease, may be, we may not be able accurately to determine ; but in the artificial system referred to, it was a peculiar oscillating feel, sometimes a thrill, and more frequently an increase in the fullness, suggestive of the *pulsus magnus et durus* of old writers. The Sphygmograph, however, may yet be able to determine this with approximate certainty ; and, though we laugh at the Chinese, it is not *impossible* that it may reveal a difference between the right radial and the left, when an organ on the right side is the seat of disease.

Laying aside Sphygmographic definition, the pulse may be briefly defined to be the perceptible distension of those arteries of the body which are accessible to touch or sight ; and in a purely physiological sense the distending process may exhibit singular variations.

There are some that are marked and familiar. The variation may be that of *interval* (increase or diminution in *frequency*), as under emotion, fatigue or exertion. Rarely it may be that of *rhythm*, the beats being unequal or intermittent; this, however, is more frequently *other* than a physiological variation. The most common form of it is probably that in which the period of rest is prolonged, due to a derangement of the sympathetic system. To say that it is, or may ever be, a *purely* physiological variation, assumes, I am aware, to decide a question concerning which difference of opinion exists.

It may be a variation of *volume*, as in the plethora of the young and robust, so long as this falls short of disease; more strictly this is exemplified during the contraction of the capillaries from cold.

The variation may be one of *duration of impulse*—that is to say, the distension may be soft and even, or have a sharp accentuation due to nervous excitement. The latter change is commonly accompanied by a sense of vibration when the ear is applied over the heart.

The shades of variation are more clearly expressed in the Sphygmographic writings, on charts 1, 2, 3, 4 and 5.

Pathologically, the variations of the pulse are of of greater significance; thus changes in *frequency*

may indicate the wide departure from health of cerebral disease or excessive fever, or the steady sapping of vital energy in any constitutional disease, when, as expressed by Latham, it has engaged the nervous system perilously. Quickness, as distinct from frequency, assumes a new signification, as in phthisis or inflammatory fever, or the impaired and irritable heart of dissipation, or excessive use of tobacco.

Volume, in a pathological sense, becomes the index of cerebral compression, of blood poisoning, of hypertrophy, or the loss of contractile tone of the artery itself.

The variation of *rhythm* is still more important, whether as the precursor of a gouty paroxysm—of the action of certain poisons, as of digitalis or colchicum; or as indicating mitral disease (Sanderson), or fatty degeneration (Dr. Todd).

Strength, as indicative of increased tonicity; and *weakness*, as of dilated left ventricle, or unhealthy blood; of ebbing life in cancerous disease; or the debility of innutrition, are qualities most familiar.

Tension, or *resistance* of the pulse, finally offers to the touch a guide of considerable importance; and when we shall come to consider its pathological value from a sphygmographic point of view, will be seen to deserve more than passing notice.

The arteries, full to repletion, are incompressible, be-

cause unable to free themselves from the accumulating blood with sufficient rapidity, and the fullness may be due to either interference with avenues of escape in front (the capillaries), or exaggeration of quantity of fluid forced into them from behind (over-working heart). In the former case a deranged sympathetic system may be indicated, and in the latter an hypertrophied left ventricle.

Before proceeding to the consideration of these variations from a sphygmographic stand-point, the cursory and brief manner in which they have been reviewed, suggests a summary, and probably no better could be given than by quotation from the work of Da Costa, on Medical Diagnosis, pp. 38 and 39 :

“ A hard, full, frequent pulse occurs in active inflammations, and in most of the acute diseases of robust persons.

A hard pulse, full or small, bounding or not, if unconnected with acute symptoms, leads to the suspicion of cardiac disease, or of an affection of the artery itself.

A tense, contracted and frequent pulse is met with in a large group of inflammations below the diaphragm, as in enteritis, peritonitis and gastritis.

A frequent pulse, full or small, but rarely tense, is the pulse of most idiopathic fevers.

A very frequent pulse, but very feeble and compres-

sible, is the pulse of marked debility, of prostration, of collapse.

A pulse frequent and changeable in its rhythm, is produced for the most part by disease of the heart or of the brain."

More particular features of the pulse-wave developed by the instrument we are considering, such as are due to elasticity, contractility or locomotion of the vessel itself, the relative tension of the venous and arterial systems, the condition of the capillary structures, etc., may be better dwelt upon, after an endeavor to understand the hieroglyphics themselves.

CHAPTER III.

TRANSLATION OF TRACINGS.

The different portions of a sphygmographic tracing, which possess any appreciable meaning, are termed *the events* of the tracing.

The first event, is the sudden, primary ascent, or shock-wave.

The second event, is the true systolic wave, or wave of filling of the vessel with blood.

The third event, is the diastolic collapse, or descending wave, the line permitted by the emptying of the artery.

The fourth event, has generally been considered the diastolic expansion or recurrent wave—the wave of dicrotism.

(In order to introduce no new element of confusion, into our subject, it will be so considered in this essay, although in some tracings there appears a wave evidently preceding this, viz., that of recoil. Instead of making it a new event, it will be introduced like compressibility as one of the general elements of a tracing.)

The shock-wave, or first event.

Sphygmographically, the pulse-wave is found to indicate several distinct occurrences. If the artery be full when the heart contracts and discharges its blood into the aorta, the first occurrence is a swiftly transmitted impulse, similar, as pointed out by Professor Sanderson, to that conveyed through a series of balls suspended in a straight line. Upon striking the first of the series the last or outer one only is propelled.

(As explained by him, when objected that this occurs only with elastic bodies, and that blood is not elastic, the elasticity of the arteries by a well-known law gives to their inelastic contents their own property). This transmission may, if the artery be full, be almost instantaneous, and is important to the proper understanding of all tracings. The writer quoted has ascertained that this transmission is at the rate of about ninety feet per second. It is at any rate frequently exhibited by a sudden ascent of the tracing just ahead of the filling of the artery; and is consequently the cause of the first wave, under the circumstances named, and indicates either one of three things (see example A) :



- 1st. Increased vigor of contraction of the heart, as in hypertrophy of the left ventricle.
- 2d. Increased irritability, due to disease of the sympathetic system.
- 3d. Increased irritability, due to simple nervous excitement.

The amplitude of this initiative wave is in direct proportion to tension.

The distinction between tracings in which this feature is due to pathological change and those in which it is a purely physiological event, may not always be easy, but even if it were supposable that ordinary means of auscultation and percussion were not available, or, as in the case of a deaf examiner, such assistance to diagnosis were impossible, there are yet two points of difference of great value: one, the persistence in disease, of increased impulse, as communicated to the hand applied over the apex of the heart—tending rather to increase during the sitting, and exhibiting a peculiar heaving motion (and suggestive, as observed by Walshe—p. 223, Dis. of Heart—of a pressure forwards, steadily against an obstacle); its increase, moreover, in extent, and quite frequently the lowering of the point of apex beat.

The other point of difference lies in the amount of pressure required to bring out the peculiarity.

Generally, unless when the disturbance of the sympathetic is sufficient to amount to disease, as in excessive use of tobacco, the increase of pressure tends to obliterate it in the simple form, while in hypertrophy a great pressure rather exaggerates it. (It is to be remarked, that simple hypertrophy of the left heart is now referred to, without dilatation or valvular disease; these complications presenting changes in the tracing peculiar to themselves.)

Should a diagnosis in any given case be of importance, the action of proper remedies and the disappearance of the wave under their use would be sufficient to establish it, for it may be here remarked that this wave of a tracing is by no means an essential one. The normal tracing of perfect health is generally a single symmetrical wave, of which the following is an example:



And in this the transmitted impulse which we have described as causing a wave of shock, is merged into the next or true systolic wave, the wave of distension or simple filling.

This, which has usually been described as the second event, is most marked when the artery is a little less than full at the time of its occurrence; and it is the prominence of this which is referred to in the axiom of

Marey, that "amplitude of a tracing is in inverse ratio to the tension."

With the instrument I have used, this axiom is correct only in a very limited number of cases, and as only the power of an instrument to ascertain and record pressure with readiness could demonstrate this, it may here be the best opportunity to refer briefly to it.

A moment's reflection would seem to make it certain that if an artery be partly empty, a wave transmitted through it would lift its surface higher, and consequently give a wider tracing than if already full; but supposing the amount transmitted be the same in both cases, the statement could be true *only* if the distensible quality of the vessels were within narrow limits, as is the case when their coats are diseased, and the quantity of the fluid therefore forced to pass more slowly; and I have not been surprised to find that as the vis-a-tergo remains in both cases the same, and the *distensible quality of the artery is very great*, the amplitude bears no *determinate* ratio to the fullness of the vessel, *i. e.* the tension. In many instances, as will be seen upon the charts appended, a tense artery which will bear the highest pressure, gives the greatest amplitude of tracing.

The explanation of this apparent discrepancy of observation, probably lies in the fact already alluded

to, viz., the adjustment of pressure in the instrument used, for if a uniform rate be employed in all cases the axiom would be universally true. With facilities for adjusting pressure, the axiom might be that “*amplitude of systolic wave appears in inverse ratio to tension when a uniform pressure is maintained upon the instrument used, but often bears a direct ratio to it when a graduated pressure is employed.*” The reason for this distinction will be obvious when considering the physiological and pathological significance of tension and its measure, compressibility. It may be more clearly explained by the observation, that when we press firmly upon or into the distended artery we obtain a measurement not so much of the distension of the vessel as of the force employed for its dilatation.

The systolic wave, or second event.

Theoretically, in a pulse we should have but two events, viz., the filling of the artery, which is more or less quick, owing to the character of the heart's action, and its emptying, which is more or less slow; and practically these are the essential elements to be considered, for it is evident that by the former would be shown any increase or diminution in the filling force, *i. e.*, any increase or decrease of vigor in the heart's action, or any interference with the current by pres-

sure or otherwise between the heart and point of observation; and in the latter, *i. e.*, the emptying of the artery, would appear any distal obstruction, whether capillary or venous.

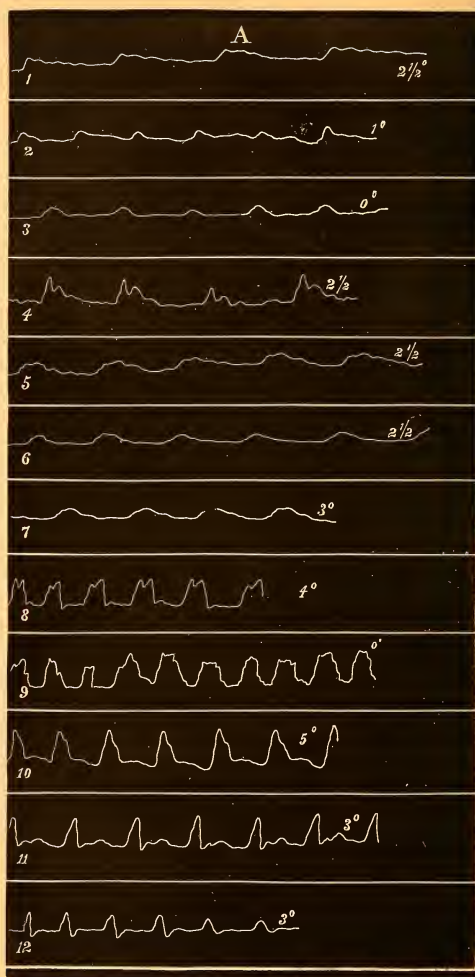
With the first of these we have to do in considering the systolic wave, or second event. As already observed, it is sometimes merged into the shock-wave, which should *precede* it. It is sometimes not at all discernible as a wave of distension, because merged into a quickly *succeeding* wave of impulse, and is subject to greater variations than any other part of the tracing.

It was formerly supposed to be most fully developed in the pulse of old age. In the following hypothetical tracing it is indicated by the letter B, and represents in the artery the systole of the heart.



It is quite frequently almost impossible to determine whether it is postponed in the tracing, and so apparently hidden by a reflex wave yet to be considered, or really takes the place of that wave.

The reader may in such cases be able, from the amount of material furnished, to form an independent opinion.





CHAPTER IV.

THE SECOND EVENT OF A TRACING.

THE tracings on the chart opposite this page are examples of varieties in this wave, including some that may be subject to two interpretations.

The first is the tracing of a healthy person whose pulse generally gave a plain smooth wave, but who in this case was under the slight influence of the fluid extract of gelseminum sempervirens, taken for experiment. It is peculiar in nothing save the smoothness with which the wave of systole is developed.

The second is of the same person, under widely different circumstances. The systolic wave begins without marked ascent, apart from the shock-wave, and is indeed probably merged wholly in it, and were it not for the slight indication of the two events exhibited in the first apex of the writing, we might suppose the shock-wave to be absent. The fullness of the artery is prolonged almost to the beginning of the succeeding pulsation. This was due to the slow emptying of the capillaries, a condition arising purely from derangement of the sympathetic system from over-taxation and fatigue.

The third is an example from a healthy woman, twenty-four hours after delivery, and after and during a profuse metrorrhagia. This rounded wave has usually been considered the evidence of slow emptying of the capillaries, and *almost always* as indicating impairment of the coats of the smaller arteries. Example number six, which follows, illustrates this condition; but there is an abundant evidence to show that this is a far too limited signification. The case we are considering is an evidence of this, for since that observation was made, tracings have been perfectly normal. Other examples on the same chart show that no degeneration of arteries would be likely to exist, owing to the youth of the parties.

In the present instance the explanation probably lies in the fact that the heart failed to fill completely during its diastole, and therefore lacked the customary stimulus of impletion, for no obstruction to circulation seems to be indicated in the tracing.

The fourth is the record of a man subject to epilepsy, but in whom no organic affection of heart or other thoracic viscera could be detected. This variety is frequently met in organic disease of the heart, but generally only when cerebral symptoms have also given trouble.

The fifth is that of an hysterical female, with no disease except uterine antelexion—the only source of

annoyance in the case arising from globus hystericus. The peculiar elevation of the systolic wave above the first is an unusual event where no disease exists, and in this case was probably due to the volume of blood discharged into the aorta with each pulsation, and a perfectly unobstructed capillary delivery. In such cases tracings may vary singularly, during a sitting, since any of the disturbances of the capillary circulation, so common in hysteria, may at any moment occur, and a state of arterial or venous tension change the whole character of the record.

The sixth exhibits the compressible artery with weak heart and degeneration of arteries of a patient eighty-one years old, suffering from chronic phthisis, and frequently from venous engorgement. This latter condition, which properly belongs for description under the subject of "tension," was in this instance always the precursor of an increase of cough and other troublesome symptoms, which compelled the patient to take to the bed.

Singularly emaciated, the veins of the body at such times, where most superficial, were prominent, dark blue and distorted. It is impossible to conceive a nearer resemblance to an anatomical preparation designed to show the veins, than the hand of this patient, yet when relieved by proper nervous stimulants, or

otherwise, they were not different from those of other emaciated people.

The radial arteries gave no indication to the touch of calcareous degeneration, nor indeed is it likely that such existed.

The seventh is the record of a young lady twenty-three years of age, suffering from aortic valvular disease. The general flatness of the wave, which has already been alluded to as a subject of some difference of opinion, the distinction between the first and second event and the prominence of the latter, as in the case of Mrs. V. (see above, example 5), are the only points of interest. The tension, as indicated by the degree of pressure requisite, is greater than in any of the preceding, and indicates a prolongation of effort of the heart to overcome some obstruction.

The eighth is the tracing of a young man, suffering from serious valvular disease. The affection followed acute articular rheumatism, and in many of its circumstances is a case of particular interest. So far as our present purpose is concerned, however, it is presented merely as an illustration of a peculiar form of systolic wave. The other features of the tracing will be explained in their appropriate place.

The ninth is a tracing taken over a subclavian aneurism, which subsequently burst, and in which a post mortem examination was made. The systolic

wave is evident in each apex of the writing, varying in each to a remarkable degree. The abrupt termination of the wave, as shown by the sharp angle which determines the commencement of the collapse, indicates the absolute want of elasticity of the vessel, and for the present is the point of chief interest.

The tenth exhibits the marked preponderance of the first above the second event, in a young lady with aortic obstruction and regurgitation. The high pressure required upon the artery is a feature of interest.

The eleventh gives probably the smallest systolic wave obtainable as a distinct event, and contrasts remarkably with the preceding. It is the record of a young man during slow convalescence from a pericarditis with endocardial complication and subsequent hypertrophy.

The twelfth was taken from the same person on another occasion. This remarkable tracing may be open to more than one interpretation, and it is not improbable that I may be mistaken in translating it, simply as an exhibit of the two events we have been studying.

If I am right, the systolic wave is deferred considerably beyond the usual time, and the artery once filled remains so till after the heart has again begun to contract. The only other cases in which I have observed

this peculiarity have been two, a victim of senile gangrene, and another, a case of advanced phthisis.

This event may have the following variety of signification :

1st. It shows the manner in which the chief function of the heart, that of supplying the blood to the arteries, is performed, whether as to force, duration of propulsive effort or method of cessation.

2d. The condition of the capillaries may by it be to a great extent determined, especially with reference to their contractility, as may be seen by reference to the changes grown out of sympathetic disorder or degeneration of their tissues.

1st corollary. The condition of the nerve supply to the heart, and the possible influence of cerebral disorders upon its action, may be to some extent ascertained.

2d corollary. It will, in most instances, determine the *volume* of blood delivered at each cardiac systole.

3d corollary. It may enable us to decide upon the condition of the mitral or aortic valves.

The next feature of a sphygmographic tracing is one that naturally follows the one just considered, for as that was a wave due to the filling of the vessel, this would show its emptying or collapse. As it is of course synchronous with the cessation of the filling force and the diastole of the heart, it has generally been termed the diastolic collapse or third event.

The third event.

This, as already said, is but the evidence of what occurs in the artery after the distending or filling power is removed. A moment's reflection will show that as the arteries are for all practical purposes open only at one end, *i. e.* toward the capillaries, it is through them that the contained blood must find escape. If it does so, other things being equal, the wave of distension, *i. e.* the systolic wave or second event of the writing would subside suddenly or slowly, in direct ratio to the freedom of exit ; but, as one may easily imagine an artery only partly full and *without any* means of escape for its contained blood, in which a propelled influx would produce distension and subsequent collapse due to a *retirement* of the wave, it is evident that the collapse may not always be a simple or easily explained event. Such is the case, and the variations in this part of a tracing are therefore of considerable importance.

It has been suggested that the period occupied by this collapse of the artery is significant, because the measure of duration of the contraction of the heart ; but that this can hardly be the case, would appear from several facts, *viz.*, that although when the heart's contraction ceases, the propulsion in the aorta also ceases almost simultaneously, yet such cannot be true of the remote arteries, and at the instant of cessation

of current at the sigmoid orifice, there is still an onward movement in them.

It is true, that this condition must be of brief duration, but as fractions of seconds would be of value in estimating the actual duration of contraction in an organ whose evolution often occurs twice in a second, this feature of the tracing could hardly be relied upon as an index of it.

Further than this, there may and often will occur in a writing what I have elsewhere alluded to as between the third and fourth event, viz., a wave probably of recoil. This may be noticed in the tracing marked four, on the chart illustrating the systolic wave or second event. Its significance will be weighed in connection with the fourth event, yet to be explained.

For the present purpose, it is only necessary to say that as this occurs during and before the actual cessation of the collapse of the artery, it must interfere with our deciding the instant of such cessation.

For examples of this event in a tracing, reference may be had to the chart above alluded to, illustrative of the systolic wave.

The slow and even emptying of the artery is seen in example No. 6.

The sudden collapse in Nos. 8 and 11.

The abrupt yet confused collapse in No. 9.

The failure of the event in No. 12.

That of the first case was due to a weak heart, but pervious though probably inelastic capillaries. With an excited or hypertrophied heart, this impairment of capillaries would have effectually prevented so even a collapse. Those of the second cases (Nos. 8 and 11) were due to aortic regurgitation.

Of the third (No. 9) to aneurism.

Of the fourth (No. 12) to commencing hypertrophy with excitement.

The chief significance to be attached to the third event is probably as follows :

1st. By it we may determine the manner of subsidence of the propelling power, such as would arise from dilated or weakened heart, or regurgitation of the blood back into the heart, whether from the aorta into the ventricle or from the ventricle into the auricle. Aside from the assistance to be obtained from other parts of the tracing, the existence of eccentric, as distinct from concentric, hypertrophy might be proximately determined.

2d. By it, also, information may be gained as to the manner of exit of the blood from the arteries into the capillaries, a matter the importance of which is closely allied to the condition of arterial or venous tension, and valuable from a physiological point of view, as of assistance in estimating the character of nerve supply and the action of remedies.

CHAPTER V.

The fourth event.

This has been variously styled the diastolic expansion, the dicrotous wave, the wave of recoil and the recurrent or reflex wave. In a hypothetical tracing it could be represented as follows, letter C.



As this wave is a feature often of importance, and has been the subject of much discussion, any new facts elicited by a new instrument may serve to settle its true significance.

Naumann and Marey have supposed it a recoil of the blood current, due to a rebound against the closed aortic valves.

Many experiments made by Sanderson have disproved this theory, and a reference to the fourth tracing on the chart, opposite page 45, affords confirmatory evidence. Experiments made by myself also with an artificial heart, and elsewhere published, seem to render such an explanation untenable. As intimated on the preceding page, the tracing just alluded to shows that the wave of recoil correctly inferred to exist by Naumann and Marey, comes when at all, *before* the

collapse, and not after, and is probably almost synchronous with the closure of the valves.

The true diastolic expansion occurs subsequently.

Omitting further allusion to the opinion of others, I may be pardoned the attempt to explain the wave by reference to my own observations, but before offering such explanation would present examples of the event under varying circumstances.

The first (see chart of 4th event) is the case of a man under treatment for persistent vertigo, of full habit, robust and broad-shouldered, but with the red vessels apparent on the cheeks, and the peculiar appearance suggestive of apoplexy without any other actual or well-marked signs of it. For the present purpose, it is sufficient to say, that the *general* capillary circulation, of the integument at least, had never been impaired. Critical examination of the heart indicated disease of the aortic valves. The tracing shows marked shock-wave, sudden collapse of the artery, and consequently either the rapid escape of the blood through the capillaries, as if by their dilatation, or a limited supply of blood at each pulsation.

In this case the slip of paper was moving slower than usual. The influence of this variation in an instrument will be hereafter considered.

The second is that of a young female suffering from hypertrophy and aortic obstruction, with possibly

aneurism of the arch of the aorta. The most suggestive evidence of the latter seemed to be a marked thrill communicated to the hand when placed on any part of the thorax.

The slow filling of the artery as indicated by the flattened apex of the systolic wave, the somewhat sudden diastolic collapse, and the irregularity of the tracing, suggest a failure of the heart to propel a great amount of blood, such as would be the case, for example, in mitral insufficiency, where a portion of the blood is forced back with each systole into the auricle. The tension is somewhat greater than the preceding, and the dicrotic wave not remarkably prominent. The case itself will be elsewhere considered.

The third is the tracing of a young man, age twenty-six, with but one arm, amputation having occurred at puberty after an accident. The patient had generally been known as a healthy, hard-working man, but at the time of observation was somewhat debilitated from over-work and anxiety. A peculiar murmur could be heard over the pulmonary valves, but no distinct evidence of organic disease was discoverable. The indications of the tracing seem to be such as would arise from impaired action of the heart due to simple debility. The skin was moist and soft, the muscles flabby, and the integumentary circulation atonic. The patient has since recovered.

The fourth is the record of a man supposed to be sound, age forty, and accustomed to much travel and out door exercise. When thus engaged he is apparently vigorous, with exception of a chronic pharyngitis, but a few weeks confinement at office-work produces languor, cough and debility. Eight or ten years since he raised considerable blood, probably from the lungs. A rigid examination gave no positive evidences of thoracic disease at the time of the observation.

Dicrotism is not well marked, and might possibly be deemed absent but for the presence of the first and second event combined in the first wave. The collapse of the artery follows, and the next ascent is therefore truly dicrotous. Here also there appears atony, either of the heart or arteries.

The fifth and sixth are both from patients weakened by disease ; the first a female with consolidation at the apex of one lung, occasional hæmoptysis and progressive debility ; the other a man age sixty, much worn by the exhausting discharges and general irritation produced by a sloughing foot, probably a case of senile gangrene.

The seventh is a singular tracing for a person free, to all ordinary means of observation, from organic disease, but debilitated somewhat by excessive use of tobacco.

The eighth is from a man of fifty, during the pros-

tration of a low form of delirium tremens—healthy so far as known.

The ninth is common in phthisis, and in this case was the record of a young man rapidly growing worse and with extensive cavities.

The tenth exhibits very plainly the wave we are considering. It is the tracing of a young lady, age twenty-eight, much debilitated by prolonged mental work, the entertainment of company, and the cares of a large household. This patient has phlebectasis laryngea and hypertrophy with aortic regurgitation.

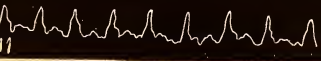
The eleventh is the case of a young gentleman with cardiac disease and debility, similar to the preceding.

Other examples of the dicrotous wave, or fourth event, will be found in a subsequent part of this work.

In summing up the examples given, one feature predominates, namely, a condition of atony either of the capillaries or the heart. We may, therefore, enquire whether this be the cause, and to what extent the phenomenon is explainable in our experience.

Two especial conditions are alluded to by Professor Sanderson in his work (p. 64), as giving rise to this wave, viz., a smaller quantity of blood than normal discharged by the heart into the aorta, and consequently a less quantity to be disposed of by the capillaries; and second, a dilatation of the capillaries by





4th event



which a *normal* quantity may be just as readily passed through them.

Experiments with the artificial heart, which need not be given in detail, show conclusively that freeness and not constriction of capillary circulation favors dirotism. The explanation of this phenomenon, which at first seems at variance with what we should expect, may be seen if we analyse the method of transmission of blood from the heart through the tortuous capillaries to the veins. As already said, when the onward movement ceases in the aorta and large vessels it is still evident in the remote and smaller ; the cessation, beginning at the heart, travels quickly toward the periphery. During the most violent portion of the propulsive effort of the heart, the onward movement may be almost uniform throughout the calibre of any given remote artery, as, for example, the radial ; but as this diminishes, the slowing of the current must appear in the part of it nearest the coats of the vessel, according to a well-known philosophical law ; the best exemplification of which is seen in a running stream. In this, the water nearest the shore moves perceptibly slower than in the center, owing to the friction. In a tube of small dimension another principle is introduced, viz., that known as capillary attraction. In both cases, however, the same thing is true ; the central part of the current is the last to fail and cease.

These two philosophical facts seem to explain in every particular the phenomenon of dicrotism. Under *all* circumstances, except those of such rigidity of arterial coats as to resist slight impressions, the condition might be educed. Careful adjustment of the instrument shows this to be true. If the arterial tissues were in a state of atonic relaxation, the wave would be increased. This also is true, for the condition has been heretofore best known in connection with adynamic fever. Were the amount of blood thrown into the aorta small, an event usually accompanied by relaxation of the elastic and contractile tissues of the body, the wave would be quite prominent. This, also, is true.

I am not aware that this explanation has ever been offered except, elsewhere, by myself; but as it appears to be consonant with practical experience with the instrument, and in no ways at variance with the experience of other observers, it has appeared to me the correct one.

In this connection it may be interesting to ascertain whether the deduction of Prof. Sanderson, that "dicrotism is characteristic of that condition of the circulation in which the arterial pressure is diminished while the venous is increased," is generally a correct one.

1st, Tracing (No. 163) was taken from a person in whom the venous engorgement was excessive, and

which was evidenced by exacerbation of weakness, and of all the unpleasant symptoms occasional during her previous illness ; so great, moreover, that the superficial veins were singularly prominent, even painfully so, and yet the chief feature in all the tracings taken was, as in the one given, the *absence* of dicrotism. Three days later the venous engorgement had subsided and the arterial pressure had increased, dicrotism being faintly evident.

2d, Case (No. 70 to 73—see chart) shows a precisely opposite condition. The patient whenever exposed to cold has attacks of vertigo, dyspnœa and faintness. At such times the veins, wherever within reach of touch or sight, are found flaccid and almost empty. The arterial pressure is very great, as will be seen by the degrees marked upon the tracings, and dicrotism is well marked. On other occasions when the equilibrium of pressure in the venous and arterial systems is more nearly maintained, the dicrotic wave is reduced or absent.

These two examples have been taken at random, and show that the deduction quoted cannot be universally true. They do not, however, militate against the explanation of the wave as given above ; and one additional and important fact may be added to this explanation as corroborative, viz., that it explains the well-known connection between dicrotism and hemor-

rhage, of which in typhous fever it is so often the precursor.

The significance of the fourth event may therefore be set down as indicating chiefly—1st, a condition of atony of the arterial tissues, particularly of the capillaries, as evinced in the dirotism of adynamic fevers; of debility from impairment in vigor of the heart, and of *reactionary* debility, as after delirium tremens. In all of these it is not improbable that the deficient tonicity is due to the condition of the inhibitory nerves. The dirotism of epilepsy, an example of which will be found in a later part of this Essay, and to which attention was probably first called by M. Voisin in the Biennial Retrospect of the Sydenham Society, 1867-8, p. 471, would form in this connection the subject of an interesting essay, so also that of asthma, vertigo, sun-stroke, etc., as seen upon the charts appended.

2d, From the very nature of the above essential peculiarity, it may be of value as a ground for prognosis when occurring during the progress of any wasting disease.

Before leaving the subject of the fourth event of a tracing—the dirotous wave—it may be in place to observe that the term has given rise to some confusion, because not literally expressing its actual meaning. Derived from *δύς* and *κροτέω*, and meaning “I strike twice,” it has conveyed to many casual readers the

impression that any break in the smooth, even wave of robust health is an evidence of dicrotism. From what has been said concerning it, this will be seen to fall wide of its proper meaning. Tracings are, in a literal sense, frequently *tricrotous*; but for purposes of Sphygmographic interpretation, not so, correctly speaking. The words tricrotic and dicrotic, as similarly derived, should be held as having similar meaning, and this meaning was settled before the invention of the Sphygmograph.

The double beat perceptible to the touch of the older physicians could arise only from the occurrence of a second impulse, late enough to fall just prior to a new systolic wave, and quite subsequent to the diastolic collapse.

Whatever, therefore, may be the number of waves preceding the collapse of the artery, they cannot be termed dicrotic; the meaning of the term, as established years ago, should and does retain its old significance.

CHAPTER VI.

GENERAL PROPERTIES OBSERVABLE BY THE SPHYGMOGRAPH. COMPRESSIBILITY, OSCILLATION, LOCOMOTION AND RECOIL.

MANY of the general properties of arteries and the circulation have been incidentally considered during the above remarks. There are, however, some of greater or less importance, deserving especial mention, viz: Compressibility (or tension), recoil, and oscillation of the circulating fluid; and of the arteries as purely mechanical contrivances, locomotion.

Of the latter quality, which is properly but an anatomical peculiarity, little need be said, save that as it is sometimes excessive, it may communicate a vibratory character to a tracing, sufficient to be mistaken for true oscillation of the blood current itself, or cause vexatious delay in obtaining a proper record. The property of locomotion grows naturally out of the elastic character of the arterial tissues, and is simply that displacement of the vessel often observable in old persons, whose emaciation renders the arteries quite superficial, or in any one, when under sufficient excitement to cause an unusual volume of blood to be forced into the arteries by the heart.

In the *former* case, the fact that all arteries elongate

under the pressure of the blood, as well as expand laterally, is quite evident to the eye, and it is probable that the locomotion is much exaggerated by the impairment of natural elastic resistance due to age.

In the *latter* case, it will be usually found accompanying great arterial fullness.

It is easy to perceive how any excess of this quality should exhibit itself in a tracing. Generally, however, the groove in the pulse-spring already described, by fixing the vessel against lateral motion, prevents the marring of the record, and the regulation of the pressure-spring utilizes the quality to increase the amplitude of the tracing.

The chief pathological significance of locomotion is probably in connection with cases of aortic regurgitation, as remarked by Dr. Corrigan.

Oscillation or Vibration.

This quality of the circulatory blood is an important one in connection with the translation of a Sphygmographic tracing. It is to be carefully distinguished from the waviness of line caused by muscular or tendinous tremor, which is of itself an interesting feature. It may be the best described by a simple illustration :

When a rubber tube of small calibre is attached to the ordinary house supply pipe, from the hydrant, the current produces to the touch no appreciable thrill ;

but when compressed slightly between the point of observation and supply, a peculiar vibration is communicated, often to such extent as to be accompanied by a low musical note. This vibration is most evident at the point of pressure, and diminishes as we recede toward the open extremity. Partially close the extremity, as by the division into smaller and branching capillaries, and the thrill is still better transmitted. Now apply the pressure more remotely, and examine in the opposite direction, no thrill or vibration is communicated in this direction, *i. e.*, toward the supply, until the pressure is made, however slightly, *intermittent*.

It is then well or ill defined, just in proportion to the amount of pressure and duration of intermission. The fullness of the tube at the time seems to exercise but little influence in the latter case, but considerable in the former.

Apply, now, this fact to the arterial system. The pressure of enlarged bronchial or axillary glands, or the simple twist of the fore-arm, which as is well known may be dexterously made to obliterate pulsation at the wrist, will sometimes communicate an oscillatory character to the tracing. As may be inferred, this would be slight or well defined, just in proportion to the amount of pressure and the fullness of the artery.

On the other hand, suppose a condition of the nervous system, such as is common in many cases, but, perhaps, most familiar in hysterical females, in which the capillary circulation is influenced by inhibitory nervous action. This action may be to such an extent intermittent as to exhibit itself in an oscillatory thrill in arteries of small calibre, precisely as in case of the intermittent distal pressure in the artificial capillaries. Examples of this are most frequent in blood poisoning by mercury, or Bright's disease, in asthma, in epilepsy, etc.

Another cause of oscillation of the blood in the arteries, may be the familiar one of aneurism. In the cases of this disease so far advanced or of such character as to cause a perceptible thrill to the touch, when applied to a neighboring artery, the waviness of the Sphygmographic line is peculiarly marked. Even in many instances, where a remote or contiguous artery appears free from any tremor under the finger, this feature is brought to light and recorded by the instrument.

Another cause of oscillation may be the direct pressure of the instrument in certain conditions of tension of the arteries. This is a fact observable with the single rubber tube already described. When this was made tense by an increase of water beyond the power of the tube to deliver readily, a very slight pressure

sufficed to produce a considerable thrill. When, however, the amount of tension was reduced by reducing the supply, a great pressure was found necessary to develop it. The deduction from these facts seems to be, that the vibration may be an index of tension. And such it *may* really be in the human system ; for an artery is in many respects analogous to the tube described. There are, however, so many modifying circumstances in the one case that do not exist in the other, that the rule is by no means safely applicable. For example, there are cases on the charts, as carefully observed as possible, in which a pressure of 100 grammes (0°) permitted the exhibition of oscillation which disappeared at 300 grammes, and reappeared at 600. The very fact that so high a pressure gave *any* tracing was *prima facie* evidence of great arterial tension ; but the disappearance of the phenomenon at the intermediate pressure it is difficult to understand. Another example, however, is explainable upon the principle described. Thus, when experimenting upon the action of medicines on a healthy pulse, 100 grammes (0°) gave a smooth even tracing, without vibratile character ; 186 grammes ($2\frac{1}{2}^{\circ}$ or 2880 grains) developed the oscillatory waves to a marked extent, while greater pressure failed to give any tracing. The inference, and a correct one in accordance with the law observed with the tube, is simply that the actual

tension of the artery was slight ; the *precise* deduction being that $2\frac{1}{2}^{\circ}$ was above a proper register.

Another source of oscillation may be the existence of a partially detached valve at the aortic orifice. A singular example of this was presented to the Essex County Medical Society of New Jersey, by Dr. Whittingham, a year since (1871). The patient, a negro of middle age, had for about a year been under observation on account of a peculiar thrill observable on all parts of the body, but especially over the base of the heart, and of considerable intensity in all the superficial arteries. To the ear, the thrill became a low, almost continuous musical note ; to the touch, it was suggestive of the vibration of a guitar string. A post mortem examination verified the diagnosis above given.

Beyond the causes of oscillation already given, it appears not improbable that another may occur from the character of the heart-beat, as in hypertrophy ; for a condition in which the beating of the heart and even of the arteries is plainly perceived by the patient, is a familiar one, and in view of the fact that a slight blow upon a filled elastic tube communicates a thrill to its contents, such a character of the heart beat might produce a similar thrill in its attached arteries.

The existence of such a cause, however, would be easily ascertained by other means.

Finally, it should not be forgotten that an *apparent* oscillation may arise from muscular or tendinous tremor—examples of which may be seen in the chart on the opposite page.

The first, is a record from a lady, just past the prime of life, suffering from a fibroid tumor of the pharynx, and having a subclavian aneurism of thirty years' standing, formerly a source of annoyance, and under the treatment of Dr. Mott of New York, but long since quiescent. The tracing is from the radial artery of the same side. The patient was perfectly free from any apparent nervous tremor or excitement, as indeed is evident in the slowness of the pulse. No other evidence of aneurismal thrill was obtainable, and the swelling, slightly prominent above the clavicle, was dense and unyielding, probably owing to nature's restorative efforts.*

The second, is from a patient twenty-four hours after a profuse uterine hemorrhage, following confinement. The tension, under the circumstances, is remarkable, but is probably due to the failure of the artery to collapse, as will be seen in the prolonged systolic wave.

The third is the record of an old man, just after amputation of the thigh at the middle third, for disease,

* NOTE.—Autopsy has since shown this supposed aneurism to have been an exostosis on the first rib, pressing upward the subclavian artery.

and exhibits simply an oscillation due to nervous shock.

The fourth and fifth are placed in apposition because similar and yet dissimilar. The first is not the correct record of the artery as regards tension, because a pressure of 5° exhibited a condition of disease of the heart and its valves, at which pressure the oscillation ceased. The arterial tension was indeed great at the time of the observation.

The oscillation is slight, and the tracing would more properly come under the head of "recoil," that wave being evident in it, but that it offers so excellent an opportunity to compare that which follows.

This is the record of a healthy man, under the influence of Gelseminum, taken for experiment (aet. 32), and the very slight oscillation is probably due to some perversion of nerve influence in the arterial coats.

This example illustrates forcibly the necessity for regulating and observing a proper pressure in order to obtain a correct record.

The sixth, seventh, eighth, and ninth appear to be due also to some perversion of nervous vitality, and possibly are connected with the inhibitory function. They are (in order) those of a man of forty-five, otherwise sound, but the victim of the abuse of tobacco ;

of a younger man similarly disordered; of a man convalescent from delirium tremens (the arterial tension in this case was considerable); and of a man with suffocative bronchitis. The last two were of middle age (40-45). In the latter the oscillatory character was greater at 4° than at 0° , as given, but exhibited other features, marring it for this illustration. At $2\frac{1}{2}^{\circ}$ the oscillation was absent, and this pressure was probably the correct register of arterial tension.

The tenth is from a delicate, hard-working female, debilitated by exhausting and prolonged labor. Vibration disappeared under a pressure of only $1\frac{1}{2}^{\circ}$, as in fact did the pulse itself. It is the irregular tremor accompanying debility, and may possibly be only the result of tendinous motion.

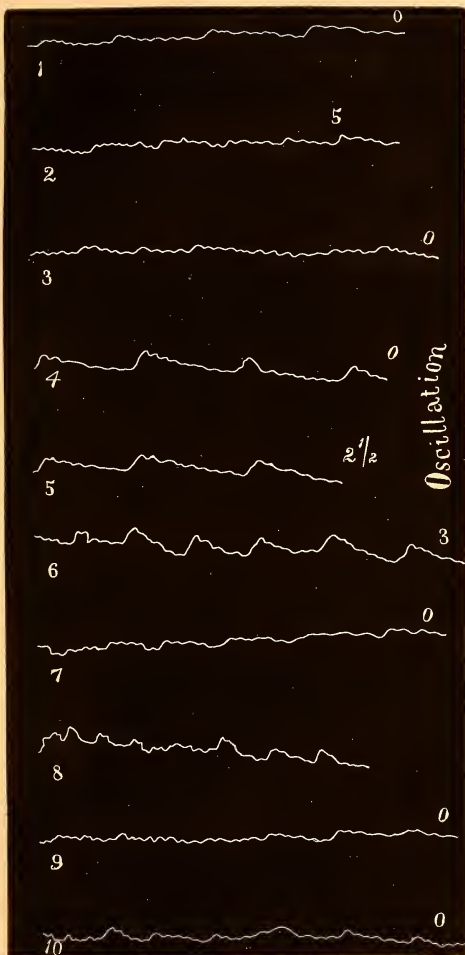
In reviewing the above cases, the fact that appears most indicated, seems to be that to some deranged nervous force is to be attributed the phenomenon of oscillation. It is, for example, marked in all cases of progressio-loco-moto-ataxia, and is best illustrated in Bright's disease, delirium tremens, asthma, and the shock subsequent to amputation.

Its significance as a feature of a tracing may be thus summed up:

Aneurism;

Distorted inhibitory function;







Severe disorder of the cerebro-spinal system ;
Compression of the artery between the point of
observation and the heart ;
Compression by the instrument itself ;
Blood poisoning, as in Bright's disease, or from
medicines.

It may be the *measure of tension*, and is the *measure of pressure as an index of tension*. It may be due to a *detached valve* or other *movable body in the large arteries*. It may be *simply apparent and due to muscular or tendinous tremor*.

CHAPTER VII.

RECOIL.

THERE will often be observed in a tracing a wave following the second event, always prior to the true diastolic collapse, and with or without the diastolic expansion, and distinguishable from the latter by its *precedence of the emptying of the artery*. It is not improbable that this wave, which seems not to have been before noticed except to be confounded with the diastolic expansion, might be developed by very patient adjustment of pressure upon the artery in a majority of instances.

As it seems to be more truly synchronous with the closure of the semilunar valves than *can be* the beginning of the collapse of the *radial artery at least*, which as occurring more remote from the heart must be a slightly later event, it may be interesting to inquire into its significance. In a hypothetical tracing it could be represented thus—D :



Examples of this wave may be seen in the records of the action of medicine upon the healthy pulse, as

in the case of *Cannabis Indica* or of *Gelseminum*. (See Part III. of this Essay.)

If in the subsequent remarks there may appear an assumption of certainty with regard to this wave and its cause, not fully warranted by the tracings adduced, it may be of interest to present here, testimony singularly corroborative of it.

In the London *Lancet* of November 10, 1866, there appeared the record of some experiments, made, I think, by Dr. Anstie, upon the difference between the pulse (as observed with a sphygmograph) of the carotid and radial arteries. A fac-simile of the tracings—upon the former—has been preserved and is given below.



Tracing of the carotid of a man with no organic disease, convalescent from lead colic.

By this appears what would naturally be inferred, if our premises are correct, from the proximity of the vessel to the heart—a *shock wave*, a swiftly-following *wave of filling*, or true systolic wave, and then, as the artery begins to empty itself of the first rush of blood, a second *shock-impulse*, synchronous with the closure of the valves.

In the radial also, it is not a difficult matter to see why such a recoil of blood should occur at such a time, or rather why an *apparent* recoil should appear, for, inasmuch as we have seen that the first event of a tracing is frequently a wave due to transmitted shock (the shock consonant with the bursting open of the aortic valves), we should naturally expect in certain conditions of the circulation that the *closure* of the valves with a shock almost equally sudden would produce a like result.

In fact, but for the difference in intensity of the two events, the latter would be *more* certain to produce it, for a more dense conducting medium has been created, and the direction of transmission is with the current. It is moreover just at the point indicated that we should search for it, viz., just before the collapse, which begins in the larger artery, has been transmitted to the smaller or peripheral. It is not improbable that in the tracings illustrative of oscillation I may have included some having this wave of recoil. Nos. 4 and 5 are open to this suspicion.

The chief significance of this wave seems to be, first, *arterial tension* (the more full the arteries the better it is developed) *not due to any organic disease*. The best examples of this will be found in tracings Nos. 25, 26 and 28, Part II.

When connected with organic disease as of the aortic

valves, in which their free falling back against the arterial wall is prevented, there would of necessity be less arterial tension, and if no regurgitation existed, the tracing, with this one exception of pressure required, would be very similar. This is exemplified in the tracings Nos. 62 and 63. In these it is interesting to note how the flattened top of the conjoined first and second waves exhibits the slow delivery of blood by the heart, as if contracting against obstruction; and also the similarity in other particulars to a healthy record. The patient was a young female with aortic valvular stenosis.

Second—A condition analogous to that which develops the most fully the first event or initiative wave of the tracing. This, as we have seen, is an increase of nervous vigor of the heart, perhaps better expressed by the word *hyperæsthesia*, and generally temporary in character. That there is a true nervous element exhibited by it is apparent from the cases in which it occurs, viz., asthma, hysteria, functional cardiac disease, and those showing the influence of *Gelseminum*, *Aconite* or *Quinine*, etc. *Cannabis Indica* produces it only when given in moderate doses.

It is probably safe to say, that it may be generally predicated of a sound organic condition when occurring with a marked “first event” in a tracing otherwise good.

Third—It is corroborative evidence of obstruction at the aortic orifice when occurring in a tracing with conjoined first and second wave, or in which a flattened wave, caused by the union of these two, drops with a perceptible angle. *Always excepting cases of high arterial tension.* Examples of these will be found in Part II. of this work.

One remark seems necessary, in addition, with regard to the occurrence of this wave as in any way the measure of tension. It has been said above, that it seems connected with a condition of tension only in health, or at least when no cardiac disease exists; and that occurring with a low arterial pressure it seems to indicate disease. Why the wave, if it be a true transmitted shock-wave, should be transmitted at one time by a full artery and again by one but partly filled, may seem paradoxical, in view of the assertion that fullness is essential to its production. The explanation however probably is, that in health a state of tension is requisite to allow a sufficiently dense conducting medium from the point of observation to the heart, but when a *prolonged* effort of the heart is rendered necessary by disease a more continuous and *even fullness exists* short of actual distension. This is evidenced by the fact that in the latter case the pressure is generally from $2\frac{1}{2}^{\circ}$ to $3\frac{1}{2}^{\circ}$, whereas 4° or 5° are necessary in the former.

CHAPTER VIII.

COMPRESSIBILITY OR TENSION.

Thus far allusions to tension have always been to arterial fullness as compared with that of the veins ; and naturally the measure of this fullness has been ascertained by the compressibility of any artery of moderate size. We have seen that under some circumstances there may be other means of ascertaining the same fact, but the best and most reliable is certainly the ability of the artery to bear pressure without obliteration. All observers have felt the need of some means, not only of readily bringing proper pressure to bear upon the artery, but of instantaneously and accurately recording it, and a glance at the charts presented will show how necessary this must be to any reliable record. In many cases of known disease of some important organ, a pressure such as has generally been used with Marey's instrument, has given the smooth even tracing of vigorous health, but a turn of the coiled pressure spring has brought out the evidences of serious disorder.

This may be true of even a dangerous cardiac disease, and therefore, no accumulation of records without this would be of practical value.

It is indeed often desirable or even essential to repeat observations with the same pressure, and to depend upon the other means indicated in the preceding remarks, to determine the fullness of the arteries, as in the recorded experiments upon the action of certain remedies ; for valuable time would be wasted in taking several tracings at the very short intervals allowed, but in examining the same persons on different occasions, tracings should be taken at various degrees of pressure in order to be positive as to the correct record ; for, in most instances, the highest degree which the artery will bear without obliteration is by no means the measure of tension, nor may it give the tracing of greatest amplitude. Generally, the amplitude increases up to a certain point, and then gradually lessens with increase of pressure. This point is undoubtedly the correct one at which to complete the observation at the sitting. From this it is evident that single tracings are not rightly comparable. Groups are requisite, and the reader may thereby be enabled to draw a correct deduction.

The importance of ascertaining the compressibility of the artery as a means of arriving at a correct tracing is self-evident ; but as an independent quality of great significance, and as one having a meaning apart from the waves of the Sphygmographic record, it deserves especial mention.

It often appears impossible to press upon the radial artery with the finger with sufficient force prevent its pulsation. Even when this seems to be accomplished, at the point of pressure it may be seen pulsating a little below, and it is evident, therefore, that the propulsive power with which the blood is driven into the capillaries may be enormous. As this point has been satisfactorily studied by the eminent physiologists of the present day, it is doubtless too familiar to bear discussion, but the degree to which it may vary under different circumstances, is of great pathological importance, and comes within the sphere of Sphygmographic observation.

By the amount of tension of the arteries, or, to express it more clearly, by the extent of accumulation of blood in them, we may infer the amount in the veins, the conducting power of the capillaries, and the condition of the heart.

From these three, as starting points, a wide range of physiological and pathological conditions may be decided. If we recall, for a moment, the experiments of Dalton upon the sympathetic nerves, their influence upon vascularity and nutrition, when divided or subjected to galvanization, or their connection with the cerebro-spinal system; and the patient investigations of Bernard into their influence over the phenomena of organic life; or consider the intimate relations between

the nervous and vascular tissues throughout the body, the effect of digestion, of exercise, of fatigue, of stimulants, of medicines, of temperature, or of emotion, upon the blood in arteries or veins; or think of the heart enfeebled by disease vainly striving to maintain the equilibrium of pressure so essential to health, we realize the importance of the quality we call tension.

When the familiar examples of contracted capillaries, as from severe cold or the influence of sudden fright, present themselves, we fail perhaps to think of the over-burdened arteries that are unable to rid themselves of the accumulating blood; but in cardiac disease so serious as to make the accumulation a new burden to the already over-taxed heart, these minor conditions attain a vital significance.

In such cases, the question as to whether the maximum of pressure shall be in veins or arteries, touches the life of the individual.

In cerebral diseases, in congestive or inflammatory stasis in different organs, in the damage done by dram-drinking, in the relapses that occur during convalescence from certain fevers, where the change in the capillaries is the first sign of change in their nerve supply, and the evidence of this in the compressibility of the arteries, is to us the warning of relapse; and in degeneration of the tissues of the arteries, where, as

in the case of Hughes, recorded in tracings 132 to 146, the extent of the disease is the measure of the patient's chances of life, this feature of arterial and venous tension is most important.

Accurate means of ascertaining the compressibility of the arteries as being so intimately associated with the condition of the capillaries, influenced, as we know these to be, by consciousness or the emotions, opens to physiology a field of inquiry which may prove of great value.

To decide the extent to which sorrow, or love, or hatred, or anger, may affect the circulation and produce disease, is assuredly important, recognizing, as we do, their influence in this direction; and to ascertain by *any* means the influence of excitement and anxiety, prolonged as it is for months and years in this country among certain classes, is to gain an element of prognosis of human life.

To sum up the value of ascertaining the compressibility of the artery, and at the same time the meaning of the sign itself, we have—

1st. A means of obtaining and translating with approximate accuracy the record of pulsation.

2d. We may ascertain through this the condition of the sympathetic and cerebro-spinal system.

3d. We may learn the condition of the heart as to ability to perfectly perform its functions.

4th. We may by it learn the condition of the arteries, capillaries and veins.

A simple experiment relative to the effect of interference with venous circulation, and consequently with that of the capillaries, and in their turn the arteries themselves, may be worthy of record, even if for no other purpose than reference.

A ligature was drawn tightly around the forearm of a man whose tracing was first found to be normal, and writings taken at intervals of one minute.

The first of these, as may be seen (fig. 1), instantly



exhibited a reflected irritation, the first or shock-wave being prominent, although the amplitude is but slight and the tension 2°.

The second shows a slight increase of this, with diminished amplitude and greater frequency — the recoil wave more pronounced.



The third shows the beginning of tension due to the accumulating blood.



The next gave no well-developed writing, except under a pressure of 5° —and in this the first and second events alone are visible, the recoil being slightly indicated but the artery failing to free itself before the next systole.



In the fifth, less pressure seemed to be indicated, probably because of the rapid accommodation afforded by the deep veins—other features remaining the same.



One minute later the tension was still farther reduced, and under a pressure of 2° the characteristic waves of an ordinary record begin faintly to appear.



At this time it should be remarked, however, that the artery yielded tracings at 5° with readiness, but not differing from the one given, except in amplitude.

This experiment, while having no particular significance, because involving only a partial obstruction of venous and capillary circulation, may yet be of interest as affording evidence of the rapidity of the accommodating powers of nature, and the ease with which we may ascertain them.

PART II.

CHAPTER I.

THE PRACTICAL APPLICATION OF THE SPHYGMOGRAPH.

THE ability of any instrument to indicate a departure from perfect health, whether capable of also indicating the precise character of such departure, or not, would stamp it of practical value, just in proportion to its power to do this alone, or more certainly, or better, than could be done by other means. There are many reasons for believing that the Sphygmograph will do all of these; that it will indicate a departure from perfect health, when not ascertainable by other means, is apparent in cases of degeneration of the texture of arteries; and if, as suggested by modern pathology, "the earliest beginnings of what may be called degenerative disease consist in structural alteration of the minutest arteries," this fact alone would be of inestimable service. Prognosis in certain diseases, the estimation of longevity, the calculation of endurance in prolonged mental labor, and the danger of such labor where certain inheritable diseases are to be avoided, would find in it a valuable indicator.

It is at once evident, that could we satisfactorily determine the variations compatible with health, the

Sphygmographic record of an applicant for life insurance would be the safest record he could present as a test of his condition ; and this single feature could hardly fail to be of great pecuniary value in a country where the assurance of life is almost universal. Those who know and lament the multitude of recklessly-made or ignorantly or fraudulently-made certificates of soundness, are aware that hundreds of thousands of dollars are annually sacrificed that might be saved by some such means.

It is believed that in the charts presented will be found most, perhaps all the variations due to other influence than disease, although still further investigation is essential to establish arbitrary rules with regard to them. Many observations in cases of known disease, or where it has been suspected, and impartial comparisons with a view to arrive at truth, will also be found in detail.

To the professional reader, who looks over a multitude of sphymographic tracings, the first impression is not infrequently one of disappointment. There is a sameness at first apparent, which would tend to suggest the inefficiency of the instrument as a means of diagnosis, or even of ordinary usefulness ; but such is also the case with the hieroglyphs of Egypt, the characters of the Chinese and Japanese language, or even with the facial features of a barbarous

nation ; yet in one case as in the other, upon every minute angle or curve, there is a significance, and careful scrutiny or maturer knowledge will reveal it.

That there is a peculiarity in each tracing is best seen by taking one of any kind, except the smooth uninterrupted wave of exceptional health, and comparing it in succession with others arranged upon a chart. Frequently fifty, sixty, or more, will be passed over, and no satisfactory similarity appear. This, however, it should be remarked, is not the case, if, confining ourselves to what we have hitherto discussed, we compare particular points in tracings, for example : similarities in venous or arterial pressure, in amplitude of systolic wave, or suddenness of diastolic collapse, etc.

Although the tracings originally presented with this essay have been reduced in number, from 1,000 to 275, yet even so large a number as the latter will perhaps seem superfluous, if judged from the standpoint of our present limited knowledge, and looking only for the features enumerated ; but as in the details of interesting cases the most useful facts are often elicited, so with cases whose clinical significance is recorded by the impartial pen of the Sphygmograph, only in details can be furnished the information we seek, and of these the student can for himself judge the practical value.

These tracings are designedly arranged in a somewhat promiscuous manner; they are selected from among several thousands, and though incomplete and unsatisfactory in many instances, the enormous extent of the field of inquiry to be thus explored, the maze of uncertainty and doubt that has surrounded the efforts of workers hitherto, and the fact that each disease should require weeks and months of patient investigation, must be the apology for such incompleteness; it is a necessity growing out of the magnitude of the work.

The whole practical value of the Sphygmograph can, in fact, only be ascertained by the completion of a dictionary, to which each individual tracing can be referred for interpretation, and towards this object these tracings are a contribution.

Another reason for presenting, in such profusion, tracings not at first strikingly dissimilar, is that to the reader or student may be furnished the amplest means for study of their value.

Careful scrutiny and comparison are invited, since the more minutely they have been studied by myself, the more firmly has the conviction grown that our present attempts at translation are defective, and that there yet may be found new keys that will unlock features of new interest. The difficulty of finding a tracing to perfectly correspond with one we may wish

to translate has already been referred to, but is made remarkable by the fact that the tracings of any one individual always indicate a singular resemblance, however great the interval of time, provided, of course, that no new or greatly exaggerated disease shall have intervened. This resemblance is suggestive of the features of the man himself, changed by the form of the beard, the advance of years, or the defacement of illness or trouble, it is yet the face of the same man and rarely loses its peculiar characteristics.

To make the study of these and similar records of value, certain rules should be observed, e. g. tracings taken at *different pressures* ought not to be compared. (This was done on the charts originally presented, but solely for illustration.) *Single tracings* should not be compared, but the several tracings of each sitting should be combined.

It should not be forgotten, that as tracings at different pressures cannot be *all* characteristic of the condition at the time, where several are found differing materially, only that should be considered significant which brings out the most fully the different elements of the pulse wave.

NOTE.—All the tracings herein given are from the radial arteries, not copies or fac-similes, but the tracings themselves as they fell from the instrument.

CHAPTER II.

DESCRIPTIVE NOTES IN CONNECTION WITH TRACINGS.

As already stated, one of the first steps in the application of the Sphygmograph to physiological or pathological study, is to ascertain the variations compatible with health. To do this, numerous examples have been selected, in which a rigid examination by the ordinary appliances of modern science failed to detect organic disease, and observations of these are given as made under different circumstances.

The first two tracings (Nos. 1 and 2) are those of a physician of middle age, in robust health.

The even wave, at a normal pressure, is a satisfactory index of the condition of the heart and general circulation. At a greater pressure, after exertion and excitement, there was a prominence developed in the wave of recoil. At a still greater degree of pressure, and after loss of rest and fatigue, there appears a suspicion of disease. (No. 2.)

Reflecting, however, upon the influence of nervous prostration in producing capillary contraction, and slight increase of arterial tension, and that the roundness of the systolic wave when resulting from disease, generally accompanies a much *higher degree* of arte-

rial tension, the tracing may be considered not inconsistent with health.

A comparison may be made with other tracings, e. g. No. 180, of a man who exhibited certificates to the effect that he was suffering from immense aneurism of the abdominal aorta, and is interesting as corroborative testimony that the man was an impostor; certainly his tracing was indicative of *no serious* departure from health, and careful examination failed to detect the disease. (See Aneurism.)

Tracings Nos. 3 and 4 are the record of a young man addicted to the excessive use of tobacco. The perverted nervous element in the wave of primary shock, and of recoil, are the only features of interest.

The same exhibition from a different, yet analogous cause, is seen in the writings of Asthma. (See Asthma.)

Tracings 5, 6 and 7 are from a gentleman mentally overtaxed, but in whom no organic disease could be found.

The next tracings are illustrative of the influence of various minor disturbing causes. The first (No. 8) appears to show the smooth wave of health at a pressure of 0°. The exertion of running up stairs quickly made a variation in arterial tension of $2\frac{1}{2}^{\circ}$. The smoking of a strong cigar also varies the tension to a slight extent (No. 10). Smoking to faintness at once reduces

this to 0° , and modifies the tracing to an extent, showing impairment of the heart's propulsive power (No. 11).

A full meal does not appear to influence the tension of the artery, nor, indeed, to modify the record of health first given, except as to frequency. The same, with wine, however, changes it as to frequency, amplitude, rhythm, and tension (No. 12). Under a less pressure there appeared a slowness of collapse of the artery, but no other change.

After exciting news a change occurs, almost like that due to faintness, and probably explainable in the same way, although the pressure differs (No. 13). Anger, however, an emotion similar to that of surprise and excitement implied in the former example, while not modifying the tension of the artery, exhibits the increase of excitement in the heart itself without the discharge of any increased volume of blood from its aortic orifice; an event, however, which would probably result at a later period, if the emotion were prolonged (No. 14). The last two examples, taken during a condition of fatigue, will probably need no additional comment (Nos. 15 and 16).

The following cases, also of apparent health, show the effects of obtaining a correct estimate of pressure employed in the observation, and the possible significance of a former disease. Please observe, *these are cases of apparent health only.*

Tracing No. 17. A suspicion of cardiac complication, growing out of rheumatism, is indicated in the tracings of this case, as brought out by the increase of pressure upon the instrument up to 2°. The patient, a male, age 30, had frequently suffered from cough and suggestive evidences of tendency to pulmonary disorder; yet, although delicate, he could not be said to be actually ill.

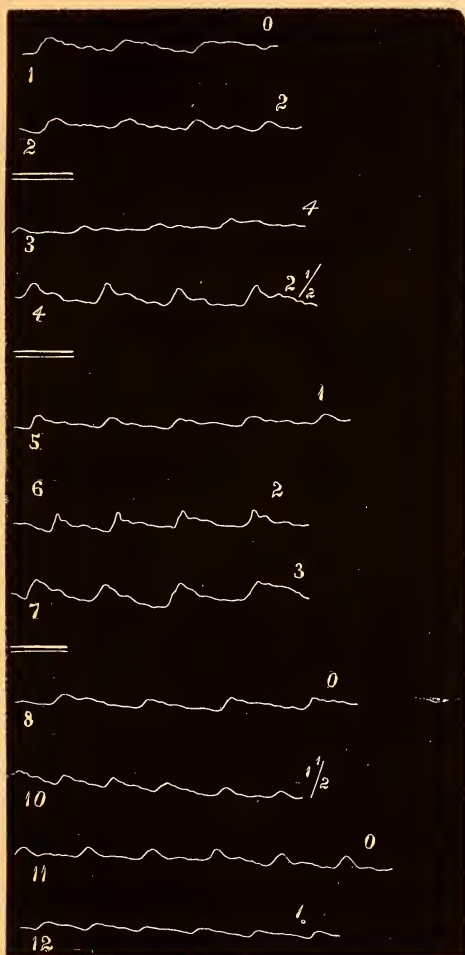
Tracings 18 and 19 exhibit nervous elements, due to widely different causes, and, in 19, actual valvular disease has been since detected.

Tracing No. 20. This tracing is the record of a man in apparently robust health, yet occasionally subject to pain over or in the apex of the heart. No lesions could be detected by examination. At the age of 25 he had raised blood on several occasions, but, neither at the time nor subsequently, was there any cough.

A man of nervous energy and business talent, he has attained prominence and wealth by his own exertions.

Tracing No. 21. This is the record of a lady, age 50, subject to attacks of suffering from a chronic ovaritis, but whose lungs were found to exhibit evidences of former and somewhat serious disease.

Tracing No. 22. This case is one of considerable interest, since, although to all appearances in vigorous health, any confinement at in-door work invariably



produces debility and cough. A man of about 42, of sanguino-bilious temperament, accustomed to travel and to out of door pursuits; he maintains a condition of apparent health, the only exception to which, is a trivial indigestion and follicular pharyngitis. Fifteen years ago he suffered from hæmoptysis, the origin of which is faintly suggested by impaired vesicular murmur at the apex of the left lung, with scarcely appreciable dullness on percussion.

Tracing No. 23. Miss G., age 18, of ruddy complexion, of petite form, vigorous and well. No organic disease could be detected, and the occurrence of palpitation and simple functional disorders alone existed, probably due to inordinate dancing.

Tracing No. 24. Mr. J. R., age 30, phlegmatic temperament, addicted to abuse of tobacco, and subject to slight cardiac disturbance.

Tracing No. 25. Mr. M., age 32, sanguino-nervous temperament, robust and vigorous, but suffering occasional cardiac disturbance from abuse of tobacco. The condition of nervous hyperæsthesia and its influence in producing tension, shock wave, and wave of recoil, are plainly indicated in the writing. This case may be compared with one of suffocative bronchitis, being singularly like and yet unlike (No. 26). It is not improbable that the condition of the pulmonary circulation, arising from the suffocative bronchitis un-

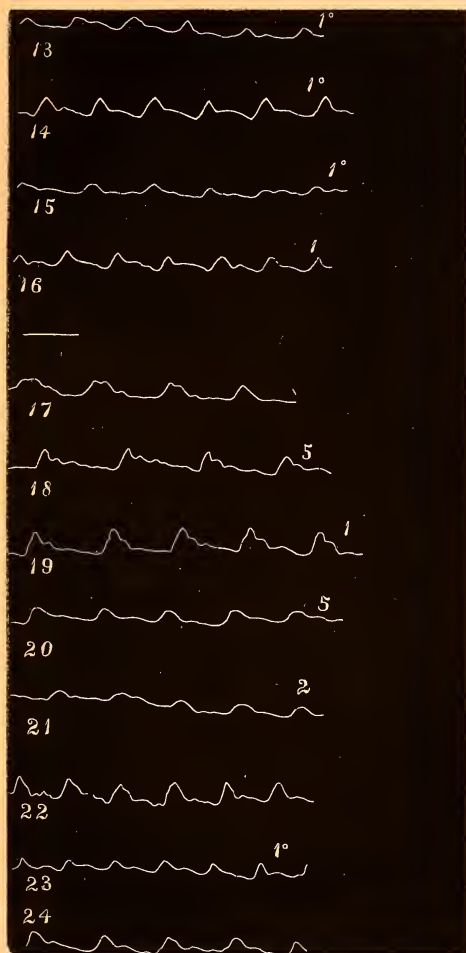
der which the patient labored, may be the cause of the prominent recoil wave, and indicative of obstruction sufficient to react on the right ventricle, and so through the left upon the systemic circulation.

Tracing No. 27, is that of a gentlemen, Mr. H., age 23, pale, nervous and debilitated, and exhibiting the marks of other excesses than tobacco, to which, however, may be attributed the principal amount of nervous depression. The marked difference exhibited by the tracings of such a person, whose arterial tension was not abnormal, and the preceding, is of interest.

The indication is simply that of reaction after prolonged nervous excitement.

Tracing No. 28, Mrs. V., age 34, married, and to all appearance and examination sound, with the exception of anteflexio uteri and globus hystericus. The comparison of this with cases of disease, can only be reconciled by the fact of difference of pressure.

A singular resemblance of the record to one common in obstructive valvular disease, but which it is unnecessary to give in this connection, shows several facts already alluded to in the preceding pages. First, that obstruction at or near the heart will produce a prolonged and flattened systolic wave, as marked as may be produced by obstruction more remote; and second, that the wave of recoil, when co-



existent with such a systolic wave, means, *except when the tension is great*, organic disease.

Were this exception not true, the records of Nos. 25 and 26 would seem to mean organic and not functional change.

Tracing No. 29, Miss P. W., age 26, suffering from debility, ascribed by herself and friends to simple nervous derangement, came under observation for a supposed cancer of the uterus, having seven months previous, undergone the torture of removal of a benign growth from the right breast by caustics at the hands of a charlatan. This growth, there is abundant testimony to prove, was of long standing, painless, not growing and *not* cancerous. No uterine disease whatever was found, nor indeed, any other organic trouble; the chief and only symptom of note was a pulsation of the abdominal aorta when the patient was lying on her back, sufficient to be perceived across the bed chamber and to lift the bed clothing.

The tracing is of the right radial. The abdominal aorta and other radial gave a similar record, varying only in amplitude.

The feature of interest in this case relates to diagnosis. From the tracings obtained, the opinion was given to the relatives that no organic disease existed, but that the pulsation was due to deranged nervous action, probably of the tri-splanchnic system, and that

the disorder would disappear under a simple course of tonic treatment.

Subsequently this opinion was verified by the recovery of the patient. The case of cardiac disease in the patient with phlebectasis laryngea, (already alluded to in connection with description of the 4th event, see No. 64,) while similar, yet differs in essential points, and illustrates by its recoil and primary shock wave, occurring with flattened systolic distension and low compressibility, the existence of organic disease. In the former case the backward inclination of the primary ascent would indicate a singular predominance of some nervous element.

Tracings 30 and 31. These were both apparently healthy men of 30 and 33 years of age, respectively, who had lost each the left arm some years before. Taken as extremes of difference in cases of men free, to all ordinary modes of detection, from organic disease, they show that in both there was departure from perfect health. In the first, more careful examination revealed a peculiar murmur with the cardiac systole, loudest over the innominate artery. The young man was found also to be suffering from malaise due to overwork.

The murmur has since become almost inaudible, but the tracings remain the same. How far the loss of arm may be the cause of the record it is impossible

to say. The other case, in which the arm had been amputated, exhibits the oscillatory motion of the blood in a normal tracing, due to the simplest of the causes assigned for this phenomenon, (see p. 72) viz: distorted inhibitory function; and in this case arose from an excessive nervous vitality and impatience to be away. The patient was a mail carrier, leading, of course, an out-of-door life.

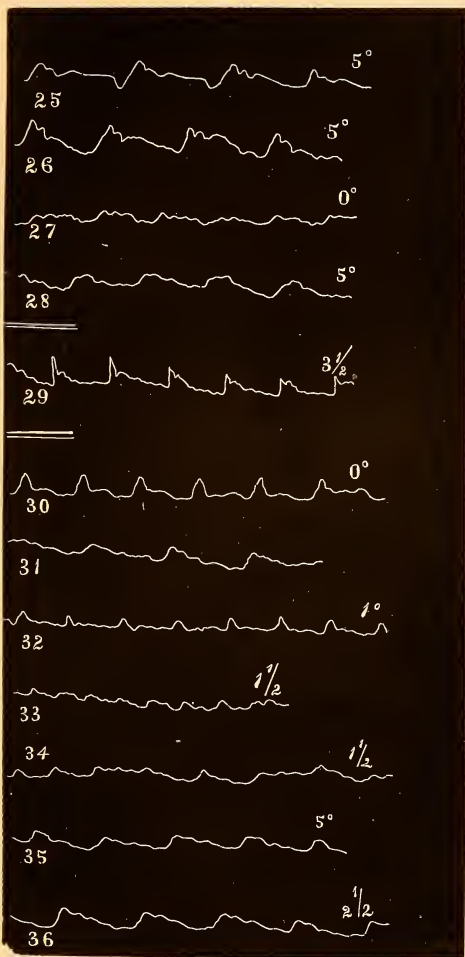
Tracings 32, 33 and 34. These are designed to illustrate the variations due apparently to debility. The pressure, it will be seen, is slight. While many other changes in tracings are undoubtedly the results of debility, these have been selected as more frequently occurring than others. Household cares, prolonged anxiety, the bearing of children, etc., seemed to have been the cause of the impairment of health.

Tracings 35 and 36. These tracings, from an hysterical female, exhibiting a high degree of arterial tension, were unaccompanied by any evidence of disease, whatever; the person being a young lady, age 18, vigorous and sound so far as a most rigid examination could show her to be so. The high tension was ascribed to functional disturbance, although the lady's father and other relatives have suffered from cardiac disease.

Tracing 37. This is from a lady subject to hysteria, but, unlike the preceding, *not* otherwise sound;

a prolonged leucorrhœa and displacement of uterus having induced a condition of impaired health. She was married and the mother of several children. The tracing is, however, submitted as that simply of hysteria.

Tracing 38. This exhibits the injury to the nervous system that may arise from excessive use of tobacco ; the person being a thin, delicate male, aged 33.



CHAPTER III.

CASES CHIEFLY OF CARDIAC DISEASE.

Tracing No. 39. Mr. C., age 24, has suffered from much cardiac disturbance, faintness, palpitation, and, at times, slight irritative cough. The low tension, the nervous element, and dirotism are chiefly marked, and were connected with capillary relaxation, due to dissipation. An existing increase in cardiac impulse does not appear in the tracing, probably because not transmitted as far as the radial artery. The patient has since recovered.

Tracing No. 40. A man, age 68, with all the external and familiar evidences of advanced cardiac disease, and with the double beat of the heart faintly perceptible in the peripheral arteries. The irregular form of the tracing is a point of interest, not hitherto dwelt upon in this essay.

Prof. Sanderson, in his work on the Sphygmograph, p. 35, describes the peculiarity for the first time, and ascribes it to the mechanical effect of inspiration during a mitral disease, accompanied by regurgitation. Such it probably is in this case, the short and ineffectual beats occurring during inspiration, the others

during the respiratory pause. He speaks also of a similar pulse due to certain dyscrasiæ, but, as I have thus far failed to observe it, time need not here be taken to dwell upon his brief remarks concerning it, particularly, as the dyscrasiæ referred to are not specified, nor tracings given. He, however, ascribes the failure of the heart, as evidenced in the short beats here given, to the non-closure of the mitral valves at the time of inspiration, and their partial or perfect closure when the relaxation of the pulmonary capillaries, during the respiratory pause, allows the auricles to free themselves sufficiently from their state of distension to permit the valves to fall together. Another and most interesting case of this disease is given in connection with tracings 74, 75 and 76.

It should be remarked that these changes in amplitude of the waves occur when the regurgitation and other disease are such that the valves are not permanently kept open. In the latter cases, the valves failing to close even during the respiratory pause, the efforts of the heart are *all* short and ineffectual. The effects of stenosis of the mitral valves, or such obstruction as to interfere with a perfect and rapid filling of the ventricles from them, would, of course, present different tracings, examples of which will be hereafter given.

Tracings Nos. 41, 42, 43 and 44. These are from a

case of threatened apoplexy, in a man with pre-existing baso-systolic murmur, showing influence of treatment and relief of vertigo. Mr. O., age 52, of florid complexion, short neck but not particularly apoplectic in appearance, formerly a butcher, for two years book-keeper, and for many years robust and well. Having been, for a year, subject to slight attacks of dizziness, he came under observation when these had become alarming, and so severe as to seriously interfere with business. Twelve years prior to this he had suffered from subacute attacks of rheumatism, but never supposed the heart implicated in any way.

The subjective condition was as follows: Vertigo upon slight exertion, no numbness or tingling or especial headache, no impairment of sensation or motion. Recovery in two months from date of the first tracing given. Treatment: cardiac and arterial depressants and rest. The baso-systolic murmur was slight, and the patient is yet unaware of its existence. The difference between the tracings, under similar pressure, is probably due to easily aroused nervous apprehension. Tracing No. 44 exhibits the result of treatment.

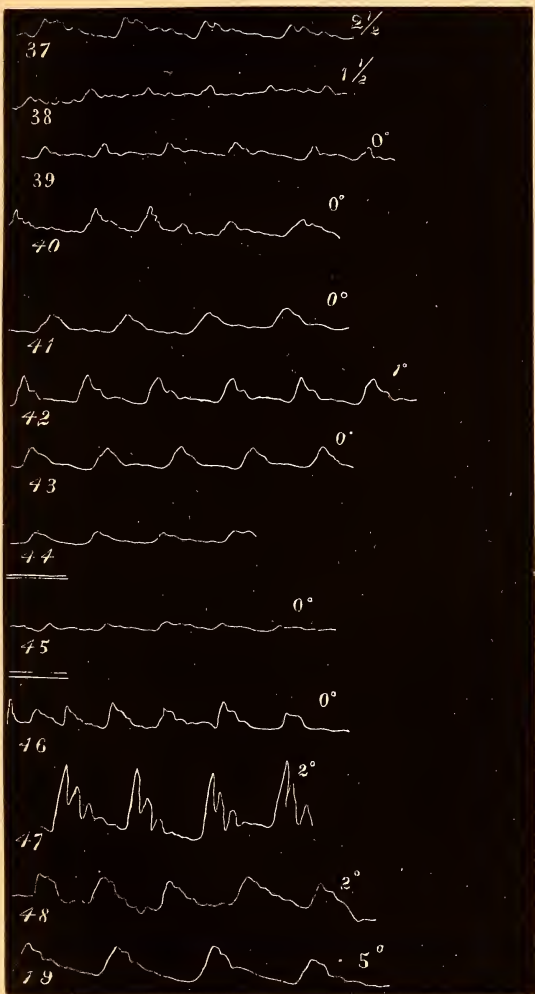
Tracing No. 45. This was a case of vertigo and threatened apoplexy *without* heart disease, the impairment being functional. The patient was a young girl, age 17, assistant to a dentist, who exhibited similar

symptoms to the preceding, but to a worse degree. Treatment the same, and recovery speedy.

Tracings No. 46, 47, 48 and 49. The record of this case is given somewhat in detail, because of the easily ascertained associate symptoms, and a personal knowledge of the patient many years. It is that of a man 66 years of age, having the appearance of vigorous health, indeed, confined to the house but once for a few days for fifteen years ; hardy, muscular, and enduring, with the appearance of a person many years younger. The tracings were taken at varying intervals, during the past two years. Formerly, and within three or four years, murmurs, both with first and second sound of the heart, were audible ; and the exaggerated impulse, increase of area of dullness, changed position of apex, etc., indicated hypertrophy accompanied by disease of aortic and intra-cardiac valves. As this enlargement has advanced, the murmurs have diminished in intensity, the impulse has grown less, and the frequency, formerly singularly reduced, (to 42 beats per minute), has increased, so that, at times, it will be found 60 or even 70 beats per minute.

The change that has occurred may be, in some measure, discovered in the comparison between the tracings.

Those taken at 2° show what variations may occur



in the same individual during the progress of organic disease.

It should be stated that, whereas, formerly (tracings not given) a pressure of 5° was necessary to obtain an ample tracing, the gradually impaired expulsive power of the heart has made such pressure, only on one occasion, allowable within the past two years. The artery no longer has the firm, cordy feeling then exhibited, although the patient is remarkably free from external evidences of degeneration, such as noticeable arcus senilis, etc.

One other feature of interest appears, viz: the suggestive resemblance, in one or more of the tracings, to the records of aortic regurgitation. In one instance only is it likely that this phenomenon occurred, and as it has never been repeated in the case, we may suppose that the obstructive disease of the valves, which undoubtedly exists to a slight degree, may have permitted a *temporary* regurgitation.

Improbable as this statement may be considered, the *record* is impartial, and the sudden collapse of the artery, from some cause, is indisputable. It is hardly, I think, to be confounded with oscillation.

The last three writings, taken at the same date, showed the importance of not accepting a single tracing, at a low pressure, as the true record of a patient; one of these, however, only is given.

Tracings Nos. 50, 51, 52, 53, 54 and 55. This case is one of pericarditis with effusion, and is of peculiar interest. It may be briefly stated, as follows :

Mr. —, age 25, of average height and weight, and dark complexion, had been annoyed for a considerable period by a cough, to him significant and alarming, because of a supposed family predisposition to affections of the lungs. After resorting to cod liver oil and expectorants, *et id omne genus*, he came under observation, somewhat weakened, and suffering from occasional slight fever. No disease of the lungs or heart could be discovered, and a chronic pharyngitis, with partial involvement of the larynx down to the ventricular bands, seemed to be the sole source of trouble. The disease of the pharynx was of the follicular variety ; that of the larynx, as would be naturally expected, glandular. No pyriform enlargement of the ary-epiglottic folds, nor other suggestion of incipient phthisis. For a real or fancied pain in the chest he smeared the whole of the front of it with croton oil. In twenty-four hours he was found with a severe urticaria, involving the whole body, and twelve hours later, with effusion into all the serous cavities of the body ; that of the joints considerable ; of the heart the least. Weakened by this disease or affection, and while the condition of the heart was far from satisfactory, he went into the country for his health,

and resorted to prolonged and violent exercise in rowing, etc., with the effect of bringing him speedily to bed, with a thoracic pain and increased pericardial effusion. During the labored action of the heart, a stasis was discovered in the apex of one lung, and a circumscribed pleurisy followed. Most rigid examinations, frequently repeated, warranted the belief that this was a result of the heart's condition, and the opinion has since been verified by the perfect recovery of the patient. Before the effusion into the pericardium had been absorbed, an endo-cardial inflammation occurred, and, as convalescence began and continued, it was evident that hypertrophy would result to a greater or less degree.

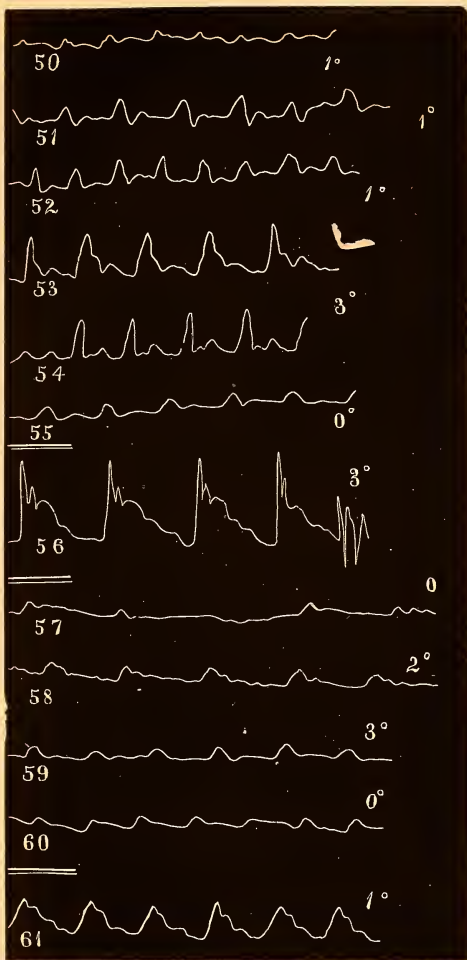
The cough, which had thus far been annoying rather than painful or distressing, continued, and when finally the treatment of the intra-thoracic disorder could be abandoned, local treatment under the laryngoscope completely removed it. After so great a lapse of time, however, (June to September,) the upper part of the trachea had become involved and required especial attention.

Dec. 1st, 1872. The lungs were found free; pulse under the finger normal, but with the Sphygmograph indicative of weakness of the heart's action. The same tracing resulted from observations at any pressure from 0° to 5° . The last tracing, unusual and

peculiar, has been quoted on chart opposite page 45. The whole case is worthy of study, and from a sphygmographic point of view might occupy a complete essay.

Tracing No. 56. This is the record of a man, age 50, in the dropsical stage of cardiac hypertrophy with regurgitation. This tracing resembles strongly that usually given by the carotid, (see p. 75).

Tracings Nos. 57, 58, 59 and 60. This case is that of a fireman, with slight hypertrophy and baso-systolic bruit, and exhibits the effect of treatment. The patient seems since to have recovered. Aside from the cardiac murmur with occasional palpitation and dyspnoea, the party suffered from sleeplessness, for which trouble he came under treatment. The relief of this by remedies permitted the development of a tracing quite different from any in the *first* series, but giving no indication of the cause of a systolic bruit at the base of the heart. The suggestion would rather be that of some mitral trouble, if valvular at all. The facts only are stated, and the diagnosis of slight hypertrophy with dilatation was made with no reference to the tracings. I have no doubt, that with greater experience and care, more satisfactory tracings could have been obtained. The greater frequency of the pulse after treatment is remarkable, in connection with the fact of complete relief from all unpleasant symptoms.



Tracing No. 61. A case of Hypertrophy (concentric), with exaggerated impulse sufficient to give thrill to the hand over the whole chest, a systolic murmur at the base of the heart, and occasional hæmoptyses without tubercle. After what has been said concerning similar cases, this one need not be dwelt upon, save to call attention to the slight pressure permitted by the artery.

Tracings No. 62 and 63. This case, that of a young lady, age 23, is interesting and worthy of a brief notice, because exhibiting the flattened wave partly due to the conjunction of the first and second events; but chiefly to the prolonged effort of the heart to force its contents into the aorta against some obstruction at the orifice of exit.

This wave aptly illustrates the description of the condition given by Blakeston (Observations on Dis. of Chest. Amer. Ed. p. 225), in which the blood is said to be *gradually squeezed* through the contracted orifice. A case of aortic valvular obstruction.

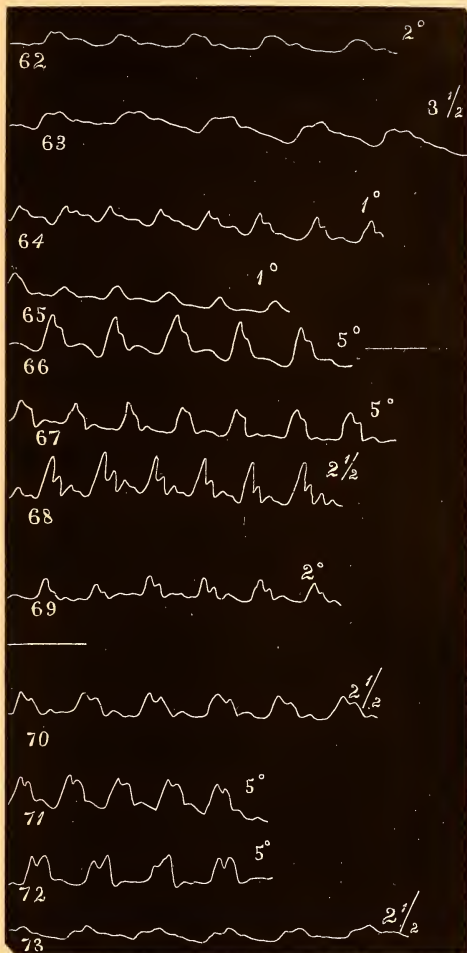
Tracings Nos. 64, 65 and 66. In this the same condition as the preceeding, is shown with an accompanying regurgitation. This case possessed many features of interest which cannot be given in detail. The principal source of trouble, for which alone relief was sought was a sense of fullness in the larynx, which was always relieved by a local application. The dis-

ease of this structure was probably due to the cardiac trouble, and, in fact, led to an examination of the heart, of the condition of which the patient was aware.

Tracings No. 67 and 68 continue the case, the progress of which was watched with considerable interest, the heart having grown steadily more troublesome. At the present time, however, after a prolonged rest, all very unpleasant symptoms, with exception of occasional slight faintness upon exertion and nervous chills, have disappeared. The results obtained by varying pressure are worthy of note.

Tracing No. 69, of a man *supposed sound*, but subject to occasional vertigo, (age 56,) may be compared with advantage.

Tracings Nos. 70, 71, 72 and 73, may be briefly described as those of a young man (age 30), with disease of mitral and aortic valves, and hypertrophy (concentric). The confusion of sounds in the chest is indescribable; and although the party has the ruddy appearance of health, these sounds, like the rushing and tumbling of many waters, can be heard when the observer is sitting close beside him. A regurgitant mitral murmur can alone be separated distinctly from the confused mixture of noises. The patient had been, prior to 20 years of age, a sufferer from frequent attacks of inflammatory rheumatism. The most inter-



esting subjective feature in his clinical history is his liability to attacks of extreme dyspnœa immediately after any exposure to draughts of cool air, or the wetting of the feet, etc.

Tracings Nos. 74, 75 and 76 are of a young lady, age 18, in whom, for eleven years, some heart disease has been known to exist. Of fair complexion and rosy cheeks, she presented to the eye no evidence of disease, yet, by auscultation and percussion, it was a matter of no difficulty to locate the seat of a serious organic change in the left side of the heart.

The tracing is a good example of that form of disease already discussed on p. 101, see tracing No. 40, and differs from the case there cited, but little, in extent of organic change. In neither, as will be observed, is there as yet any failure to fill the arteries, and while a pressure of 5° is necessary to bring out in perfection the peculiarities of the writing in the latter, (a low or normal pressure hardly suggesting the existence of the regurgitation that is so evident in the other records), yet, in the case above referred to, on p. 101, a pressure of 0° only could be tolerated, and the accompanying symptoms indicated a *more advanced stage* of the disease. Had the amount of regurgitation been more excessive in one than the other, we should probably have had *all* the waves exhibiting evidences of inefficiency in the tracing,

instead of every second and third. It is not unlikely that nervous or tendinous tremor is the source of the apparent oscillation in the second record of the series, since it is so nearly obliterated from the one that follows, under an equal pressure, and as we know the influence of nervous excitement upon a person suffering from this disease, we may correctly attribute the increased tension, also to it. Singularly contrasted as the successive waves are, the pulse to the touch but faintly suggested irregularity.

Tracing No. 77, exhibits a suggestive abnormality to which, however, the most careful physical examination gave no corroborative testimony. The patient, a young lady, age 26, of superior intelligence, believed herself to have inherited some affection of the heart from her father, her pulse having for several years been above 95. No increased area of dullness and no murmur existed, nor was the rhythm, impulse or pitch of the valve sounds at all modified. The similarity of the record, however, to that of No. 72, is interesting, in view of the family tendency to cardiac disease, and the patient's habitually rapid pulse. It may be remarked that she was and has been for years in otherwise robust health.*

* Since this record was made the patient has suffered from attacks of alarming syncope.

CHAPTER IV.

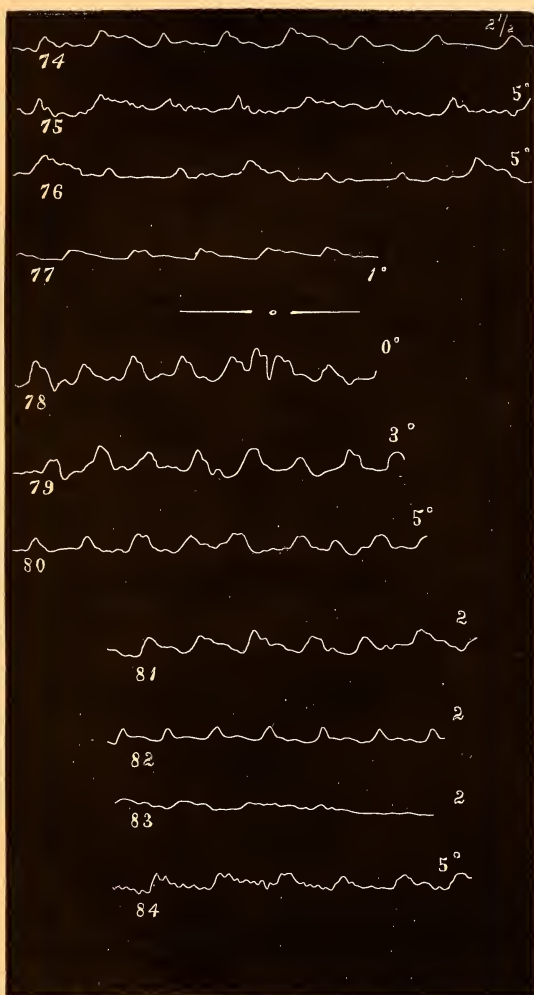
AFFECTIONS OF THE NERVOUS SYSTEM.

Tracings Nos. 78, 79 and 80. This case was that of a large, well developed, vigorous man, taken during convalescence from mania-a-potu, or rather after the most violent symptoms were brought under control by treatment. These tracings are types of those obtained under similar circumstances, but differ materially from those given in Reynold's System of Medicine, by Prof. F. E. Anstie. What may be the cause of this discrepancy I am unable to say; but as my object now is simply to give the reader the results of personal observation, any attempt to reconcile them would be out of place. It will be observed that the amount of pressure in this case does not vary perceptibly the amplitude of the tracing.

A Sphygmographic observation taken later, gave only a low, wavy tracing, showing extreme nervous debility.

Tracing No. 81, is that of a man of 56, *supposed* well, but in whom the second sound of the heart has a peculiar intensity. He is subject to vertigo, and undoubtedly is, to some extent, unsound.

Tracings Nos. 82, 83 and 84, are examples of similar troubles; and being in no wise peculiar, time need not be occupied by further comment, save that the latter being the record of a hard drinker, quite recently a sufferer from sun-stroke, exemplifies the remark on page 73, that oscillation may be due to either "severe cerebro-spinal disturbance" or "blood poisoning," both of which existed in this case.



CHAPTER V.

CASES OF ASTHMA, AND VARIETIES OF SAME.

Tracings Nos. 85, 86, 87 and 88, are from a patient, a male, age 33, laboring under an asthma, complicated with bronchitis—a true suffocative bronchitis. The first two exhibit the combined respiratory act. The period of observation lasted from August 20th, the date of commencing treatment, to Sept. 16th, at which time all asthmatic symptoms had been relieved, and the subacute bronchial inflammation was progressing rapidly toward recovery. A state of excitement of the nervous system is evident during the activity of the disease, and one of cardiac asthenia during convalescence.

Tracing No. 89, is that of a young girl, age 9, who for six years has suffered occasional attacks of asthma. She shows, under physical examination, evidences of slight dilatation of the right ventricle, and has the asthmatic shrunk chest. She has suffered from frequent palpitation of the heart and insomnia.

Tracings Nos. 90 and 91, are the record of a life-long sufferer, age 56, who has since died. At the time of examination, being very weak, he was found to

have excessive dilatation of the heart, and double emphysema. A distressing dyspepsia added its tortures to his disease. The attacks of asthma had been nightly for thirty years, with very rare exceptions.

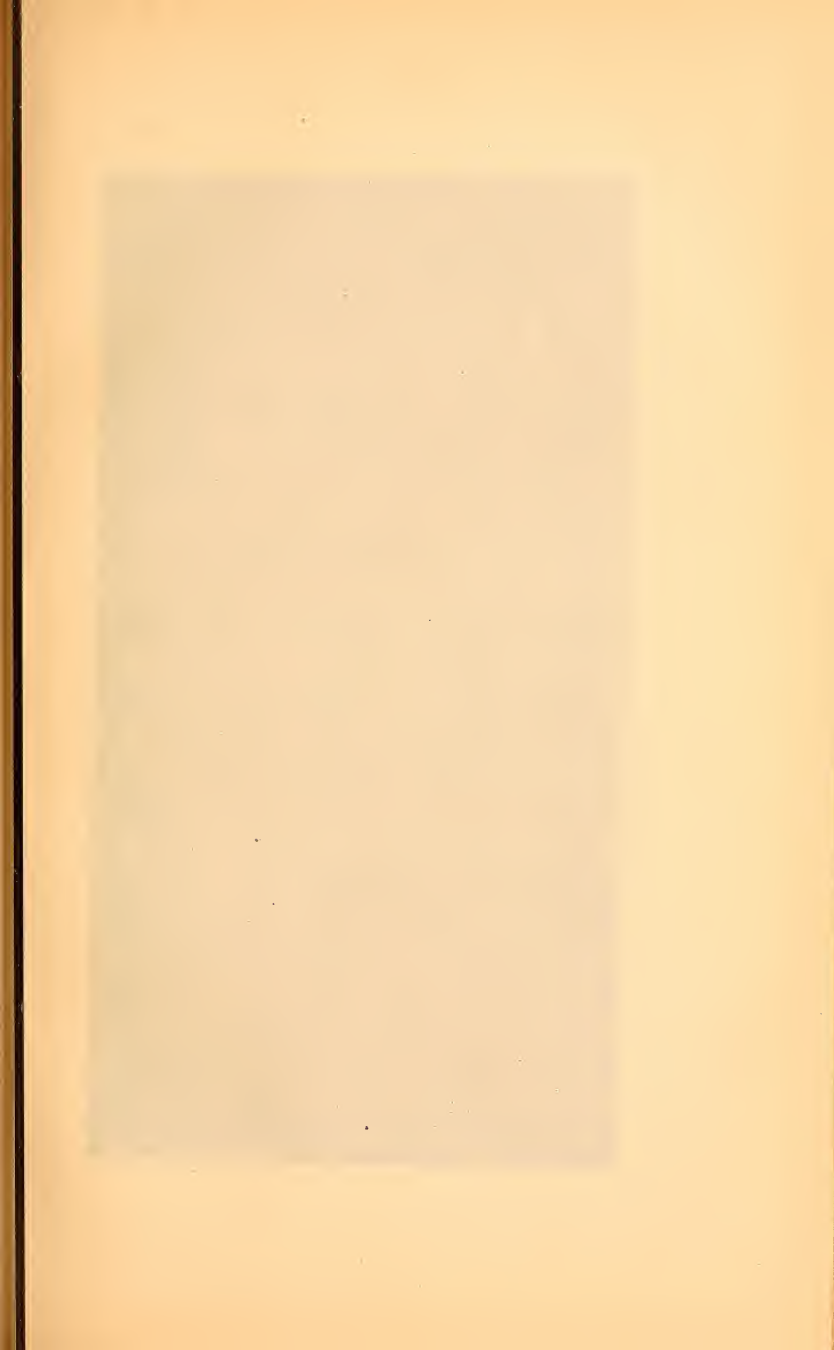
Tracing No. 92 is a case of *Autumnal Asthma*, accompanied usually by bronchitis in a severe form, but this year with but slight implication of the bronchi. A male, age 40, a brewer. A curious fact in this case is worthy of record. Each year, after recovery, he has for several years voided urinary calculi (mulberry variety) in considerable numbers, although no symptoms have ever pointed to the kidneys as a source of trouble at other times, and never during the paroxysms. The record was made during the day, the attacks being usually at midnight or shortly after.

A high degree of pressure was necessary to produce an ample and satisfactory tracing.

Tracings Nos. 93 and 94 represent the record of a robust man, age 32, for five years a sufferer from true *uncomplicated asthma*; attacks diurnal, sudden, protracted and severe.

In this, as in all cases where not otherwise explicitly stated, the tracings given were taken before the use of remedies, and during the day.

Tracing No. 95 is from a lady, age 32, suffering from *cardiac dyspnœa, supposed to be asthmatic*.





The heart is hypertrophied, the apex beat being above the fourth rib, and displaced $2\frac{1}{2}$ inches to the right; systolic sound double, and diastolic very sharp at the base and also at the apex of the left lung. (The urine in this case was found on several occasions highly albuminous.)

Tracings Nos. 96 and 97 are from a robust man, age 42, with ordinary *autumnal asthma*, beginning, as is usual in such cases, in August of each year; no marked complications.

Tracing No. 98 was similar to the preceding as regards the age of party and character of the disease, but differed in being *not* autumnal. The patient, a sea captain, has been long subject to slight bronchitis, with asthmatic difficulty of breathing, whenever remaining a few nights on shore. He was found to have consolidation, without softening or outward symptom, at the apex of the left lung.

Tracings Nos. 99 to 111 inclusive, are examples of supposed *progresso-loco-moto ataxia*. In all of them there seemed but little doubt as to correctness of diagnosis, and in the first two (99, 100, 101, 102, 103, 104, 105 and 106,) no corroborative symptom was wanting. In the others the impaired co-ordinating power, the severe neuralgic pains, the duration of the affection, the occasional ptosis and the limitation of the distinctive phenomena to the lower extremities,

were present, and the absence of any symptoms pointing to other cerebral or spinal disease, seemed to warrant the diagnosis given, although the youth of one of the parties was somewhat against the correctness of the opinion.

(Case 99 to 101 inclusive.) Mrs. B., wife of Judge B., aged about 50, ill five years; duration of marked inco-ordination of motion one and one-half years.

(Case 102 to 106 inclusive.) Mr. G., age 52, duration of illness, six years. The first two tracings were taken October, 1872, the next a month later and the last two a month later still. In November the record states that "Strabismus and persistent ptosis" existed.

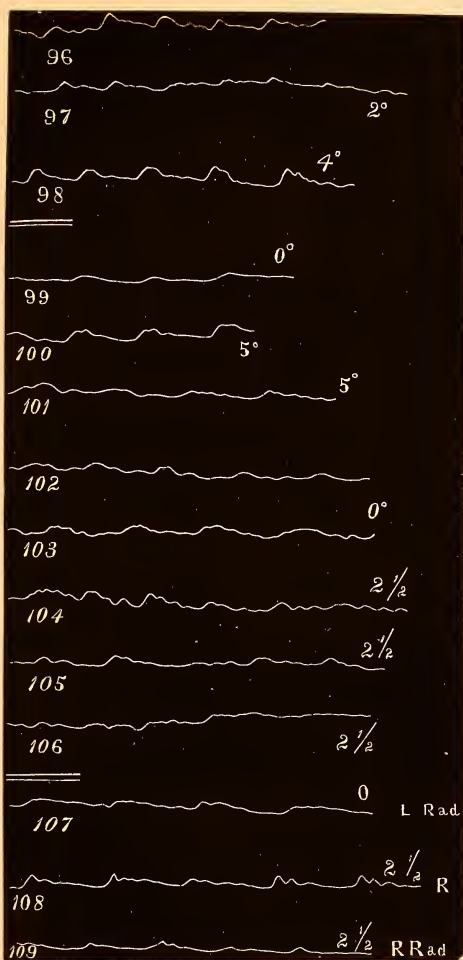
(Case 107 to 109 inclusive.) Miss J., aet 18, ill four years; unable to walk three years past.

(Case 110 and 111.) Mr. E., age 26, ill three years.

All the cases are yet living, that of (case 102 to 106) alone showing the approach of the end; and in each without exception, (although the fact has no bearing upon our present subject,) it may be interesting to note that amelioration and relief has followed the use of large doses of ergot and phosphoric acid. From a Sphygmographic view, several points of interest may be noted. *First*—In two of the cases, it was almost impossible to obtain similar writings from the right and left radials.

Second—In the two cases most advanced, a degener-





ation of the arterial tissues, or at least the impairment of their elasticity, is indicated.

Third—The record of the young lady, age 18, (107, 108, 109) exhibits the least aberration from a healthy standard, and a favorable prognosis based upon it alone, although made after long treatment, under other physicians, and much discouragement, has been verified in the rapid improvement of the patient. The similarity of the tracings to those taken from my own arteries, while under the influence of certain nervous sedatives, is well marked.

Fourth—The record of Mr. E., age 26, (110 and 111) while failing to justify a favorable prognosis, because of the evident impairment of the impletive power of the heart and the inference of severe cerebro-spinal disorder, drawn from the oscillation of the writings, is yet instructive. Under the treatment already indicated, combined, however, with remedies required for a distressing insomnia, the patient has so far recovered as to be free from the boring and neuralgic pains, is able to walk about with no great difficulty, to sleep and eat with the appearance of returning health.

It is by no means designed to intimate that these cases are destined to ultimate recovery ; but only to emphasize the fact that the organic and structural change appeared in them less advanced than in the others. The languor of the systolic action of the

heart, as evidenced by the slope of the primary ascent of the tracing ; the irregularities of rhythm ; the variations in frequency and pressure ; the tendency to an oscillation in no measure due to tendinous or muscular tremor (because none existed), may all be set down as marks of a serious organic derangement of some kind.

CHAPTER VI.

SINGULAR CASES.

Tracings Nos. 112 and 113. The tracings of this patient are not easily explained. A saloon keeper, age 35, and for years never ill. He was taken with chills, accompanied by alarming symptoms indicative of congestion of thoracic organs. The tracings were taken during the intermission. The paroxysms seemed without reasonable room for doubt, those of quotidian ague, running somewhat rapidly into a remittent fever. This became again intermittent under treatment, and recovery followed within three weeks.

The resemblance borne by the tracings of this case to many heretofore tabulated is somewhat remarkable; and as the changes in the records since recovery still show some abnormality, it is not unlikely that the heart at least has sustained severe damage. To all appearance, however, recovery has been complete.

As this has been the only case of the kind, of which I have obtained records, it is unfortunate that no proper comparisons can be made. The whole number of tracings made in this case, however, was perhaps forty.

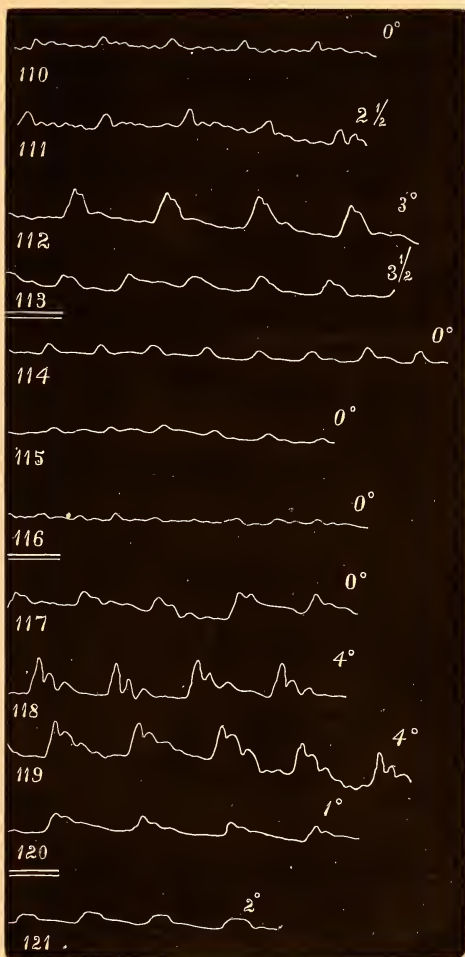
Tracings No. 114, 115 and 116. This is the record of a case of schirrhous of the breast, which caused death by exhaustion, three years after its discovery, and without operation (if we except an attempt to cure by electrolysis.)

Tracings Nos. 117, 118, 119 and 120. Mr. C., age 32; until quite recently subject to epilepsy. At the time of observation with the Sphygmograph he was suffering from acute enteritis.

The amplitude of the tracings under all pressures is singular, as also its resemblance to the writings obtained in organic disease of the heart. There can, I think, however, be but little doubt that no regurgitation is indicated, but that whether we regard the many waves as due to oscillation or the presence of waves of recoil, the translation probably is that high arterial tension and some occult cerebral affection are indicated.

The presence of a marked diastolic murmur in the tracings of epileptics is noticed by M. Voisin, in the Biennial Retrospect of the Sydenham Society, 1867-8, p. 471, but as the tracings themselves are not given, we cannot determine whether the waves were really those of the fourth event, of recoil, or of oscillation. An apparent verification of the opinion above expressed seems to be afforded by similar tracings among those of asthmatics which may be compared.





Tracing No. 121. Mrs. C., age 50. This patient came under observation for a chronic ovaritis of years standing. Examination of the whole body revealed no other *active* disease, but an impaired condition of one lung, due to a former disease, at the apex.

The tracing under a pressure of 2° would suggest either degeneration of the arteries, of which no other evidence appeared, or of obstruction to circulation at or near the heart. Whether we ascribe it to the former or the latter, two things are certain; there was obstruction to free pulmonary circulation, as well as that which grew directly out of the congestion of the ovary, and as there was no evidence either of perverted inhibitory function influencing the capillaries, nor yet disease at the aortic orifice, which would probably have shown itself by a more sudden descent from the flattened apex of the tracing under the pressure recorded; and as moreover this kind of record is frequently met in local congestion, when not connected with too great inflammatory action, it is fair to attribute the appearance to the condition of obstruction indicated, viz: in the lung and in the ovary. Further inquiry and observation are necessary, however, to establish such a point satisfactorily.

Tracing No. 122, is that of a young man age 35, suffering from chronic rheumatic arthritis, with deposits in the joints of the fingers. The record was

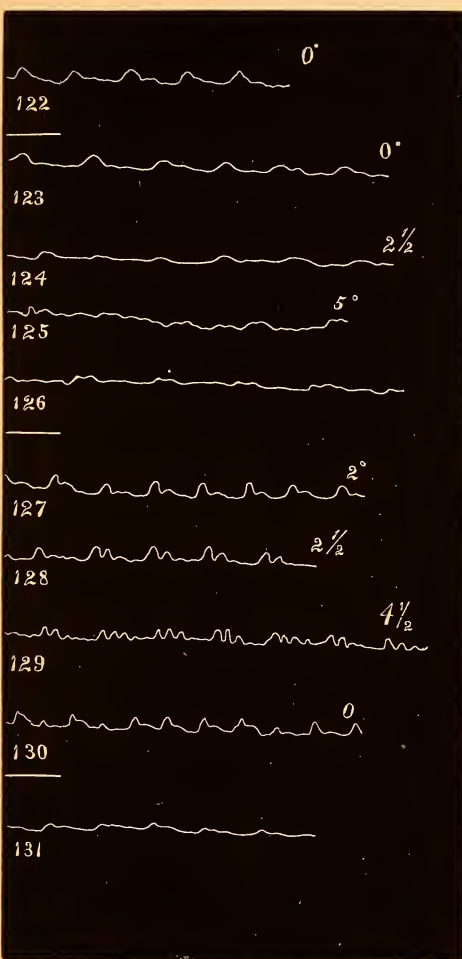
made in the interval, between exacerbations of the disease; the patient being able to attend to business, and the deposits comparatively insignificant.

Tracings Nos. 123, 124, 125 and 126, are those of a lady age 26, suffering from metrorrhagia after confinement. In forty-eight hours after the last tracing, the record gave a smooth even wave, the patient feeling free from faintness, &c.

Tracings Nos. 127, 128, 129, 130 and 131, are those of a boy, age 6 years, suffering from acute Bright's disease. The tracings were taken during the stage of anasarca, the boy presenting the peculiar waxy color, characteristic of organic disease of the kidneys. Since the last tracings, the progress toward recovery has been rapid, and is now almost complete. (Dec. 20, 1872.)

The appearance of albumen and casts no longer exist in the urine, and the pulse is fast regaining its tone and fullness. On the first occasion, there will be noticed the interrupted efficiency of the heart, faintly simulating mitral regurgitation, together with the accentuation of the primary shock wave, or first event, and dirotism under a pressure of 2°. On the next occasion, the predominance of oscillation in the blood current was singularly pronounced. On the next, and but three days later, a normal tracing appeared, (with exception of its frequency,) and under a normal degree of compressibility.





Tracings Nos. 132 to 146, inclusive, on the chart opposite, are those of a man, age 64, who for nearly a year had been suffering from gangrene of the foot, due as was supposed to degeneration of the arteries. In none of the tracings, however, was this apparent. Upon consultation, it was deemed advisable to remove the limb through the junction of the middle and lower third of the thigh. This was accordingly done, and the records exhibit the condition of the patient immediately before and after the operation. As may be inferred, his condition prior to the amputation was not particularly favorable, owing to the prolonged drain upon the system due to the nature and duration of the disease.

Aside from the history exhibited by the tracings and the appended notes, it may be briefly said that for several days after the operation, no reparative effort of nature was visible, but by the seventh day a line of demarcation was well defined a few inches above the end of the stump, and the increase of appetite and strength gave promise of recovery. By the twentieth day, however, it became evident that age and prolonged suffering had left no sufficient vitality to secure restoration to health, and he died of exhaustion on the twenty-eighth day after the operation.

Two inferences seem to me justifiable in this case, viz: that the disease was not due to any atheromatous

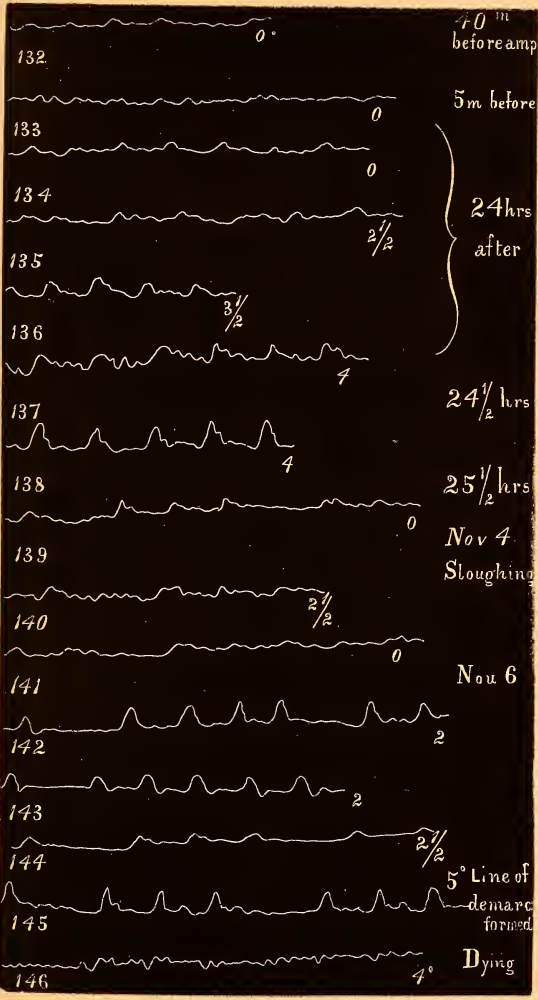
or other degeneration of the arteries, because none such appeared in the Sphygmographic record, and that the operation was therefore justifiable on the part of the operating surgeon ; and second, that inasmuch as some local affection of the artery probably existed, the operation might have proved successful, if this could by any means have been ascertained, and the amputation made high enough above it. The line of demarcation and the total want of any reparative effort in the stump, seemed to show that by an accidental selection of the point of operation, the disease was left above instead of below it.

These tracings exhibit greater varieties and better examples of the recording power of a Sphygmograph, than any given in this essay. The intermission shown in some of the tracings, and the prolonged fullness of artery, with oscillation and sudden collapse in others, are interesting.

Tracings Nos. 147 and 148, (impaired arterial elasticity; the patient a frequent sufferer from acute rheumatism, with no discoverable cardiac lesion as yet;) No. 149 and 150, (dilated heart;) No. 151, (laryngeal phthisis;) are introduced because the records of cases of considerable interest, but of questionable diagnosis. They are believed to be due to the diseases, however, indicated.

The first, for example (No. 147 and 148), was of a





man, age 55, who had been pronounced by various physicians to have both disease of heart and lungs. Subject to acute inflammatory rheumatism up to within a year, he yet manifested no outward signs of cardiac disease, and a careful examination failed to detect any organic disease whatever. There exists, however, evident impairment of elasticity of arterial tissues, and the man uses tobacco to an injurious excess.

Tracings Nos. 149 and 150 are tracings from a young female, exhibiting all the symptoms of dilated heart, and yet at times so free from them as to throw doubt upon so grave a diagnosis. The concurrence of several physicians, however, in the belief that such is the disease, and the careful observation of the patient for nearly two years, have appeared to warrant the belief that the diagnosis is correct. The case is of such variety in some respects, however, that it is unfortunate that it cannot be given in detail.

Tracing No. 151 is from a young man with laryngeal phthisis, with slight disease at one apex (no softening).

CHAPTER VII.

PHTHISIS.

The following tracings, Nos. 152 to 177, are those of cases of phthisis. Out of several hundred these alone are given, but the selection has been made to give as correct an idea as possible of the character of tracings usual under such circumstances.

The first patient (Nos. 152 to 155 inclusive) was a young man, who, when seen in February, 1871, had become debilitated by about three month's illness; softening of deposits having commenced in the apices of both lungs.

Treatment and general progress in the case are of a too familiar type, and need not be detailed. He was sent around the world, via Australia, and in March, 1872, returned, only to show immediate signs of progressing disease, which had apparently been quiescent while at sea. August 12, 1872, as stated in my notes, he had come to his bed, and suffered from hectic, night sweats, &c. August 24, 1872, he was cheerful and with good appetite, but failing rapidly, the pulse not bearing a pressure above 0° without obliteration. He died September 1, 1872.





Tracings Nos. 156 and 157 are the record of a young man, age 33, also with phthisis, but in a stage short of softening, the apex of one lung only affected, but the ary-epiglottic folds, showing the pyriform enlargement, common in phthisis pulmonalis, and the patient a subject of hæmoptysis.

Tracings Nos. 158 and 159, are from females of about 30, with advanced disease of the apices of both lungs, although not yet confined to bed. Minute record of symptoms, &c., are not given in connection with any of these cases; the object now in view being of too general a character.

Tracings 160 and 161, are from a young man whose condition may be best described by simply copying the notes taken at the time of an examination, some time previous to any marked symptoms of illness, except hæmoptysis. "Left lung—in front wavy, and interrupted inspiration and prolonged expiration, with dullness and absence of vesicular murmur as low down as the nipple. At the back, pronounced bronchial breathing above the scapula; and over a spot three inches in diameter at and below the angle, vocal resonance. Dullness most marked over the upper portion of the thorax. No crepitation or rales. Inspiratory and expiratory sounds the same as in front. Right lung—sounds normal with exception of slight dullness over the posterior portion of the thorax below the scapula,

apparently the result of previous inflammatory action."

The tracings given were taken after the beginning of softening, some months later; all others being omitted because possessing no especial points of interest.

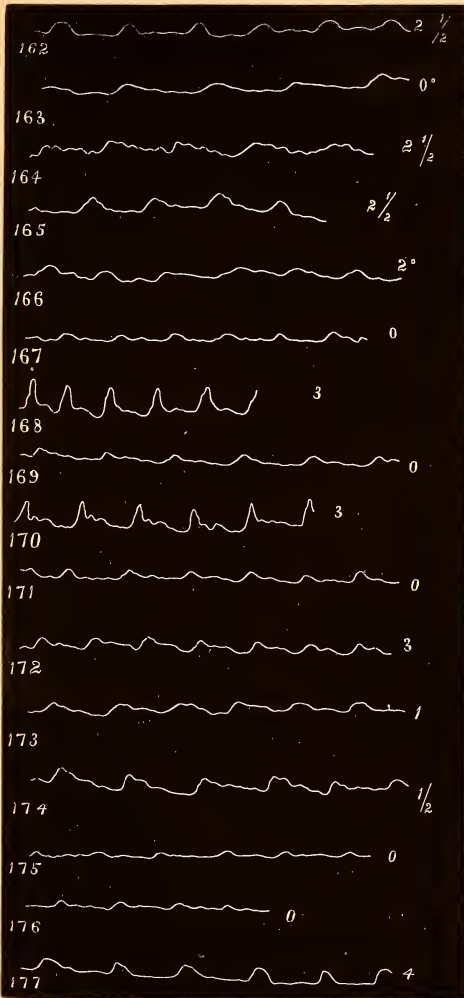
Tracings Nos. 162 to 166, inclusive, are those of chronic phthisis.

Cases 167-168, 169-170, 171, 172, 173, 174, 175, 176 and 177, are of latent phthisis, the predominant feature being often entirely unconnected with the affection of the lungs. The pathological indications in all cases of phthisis, however, excluding of course the variation due to degenerations of tissue, and inter-current diseases, may be briefly stated to be those of weak heart and atonic capillaries. These will be found especially prominent in cases complicated with hæmoptysis.

Aneurism, (see records, Part III.) The tracings of aneurism are usually what theory would lead us to expect, and the thrill perceptible to the touch at an advanced stage is simply anticipated at an earlier period by the Sphygmograph.

The tracings Nos. 178 to 180, inclusive, are presented in connection with each other under this head, simply to show the value of the instrument in diagnosis. The first tracing, 178, was taken from a man, age 50, with an immense aneurism of the subclavian artery, and although taken over the aneurism, which projected as





a swelling above the clavicle, it is a fair sample, magnified, of those from the radial artery. The patient was vigorous and free from other diseases, and, as in most or many cases of aneurism, was by no means convinced of the dangerous nature of his disease, nor assured by any unanimity on the part of the physicians who had seen him. Indeed there existed the widest difference of opinion as to the character and source of the swelling above the clavicle. A sudden death and autopsy, however, corroborated the evident testimony of the Sphygmograph.

This case may be compared with advantage with the two that follow it, Nos. 179 and 180. The first of these latter (179,) possesses considerable interest in this connection, chiefly because believed to be a case of subclavian aneurism up to the period of autopsy. No less distinguished a personage than Dr. Valentine Mott, 30 years ago, confidently decided that an aneurism ; existed and although of late years only a dense swelling, with heaving and not distensile pulsation has existed, presenting itself just above the clavicle, yet no question seems to have arisen regarding the original diagnosis. The Sphygmographic tracings, however, failed to verify this, as may be seen (No. 179,) and at the autopsy the subclavian was found healthy, an exostosis on the first rib having given rise to the error by pushing upward the vessel in its growth.

Tracing No. 180, also a case mistaken for aneurism, was one of considerable interest, and may be briefly described. The patient, a man of about 50 years of age, presented himself for sympathy and pecuniary aid, and showed a certificate signed by several prominent physicians of a well known hospital in New York, to the effect that he had an enormous aneurism of the abdominal aorta. In spite of this appearance of authority, however, a very careful examination failed to furnish to my mind sufficient evidence of any such trouble, and while not able to substitute satisfactorily any other diagnosis, the Sphygmographic tracings taken from various arteries of the body strengthened the unbelief, and the man was dismissed as an impostor. This opinion was subsequently verified by his arrest by other parties and confession. The tracing, as may be seen, shows departure from health because of dissimilarity in the successive waves, but not suggestive of aneurism.

PART III.

CHAPTER I.

INVESTIGATIONS MADE WITH THE SPHYGMOGRAPH INTO THE ACTION OF CERTAIN MEDICINES UPON A HEALTHY PULSE.

It will be evident to any one, upon reflection, that with all remedies there may be an action upon the system at large, or upon the circulation, prior to its *sensible* and *familiar* action. If this be really the case, the Sphygmograph would discover it with a measurable degree of certainty. We may also reasonably look for certain other actions, too slight in degree to be perceptible to any perhaps but the patient, yet of such a nature as to afford valuable guides to the exhibition of the drugs. It is not improbable, moreover, that the action of certain poisonous remedies might be so perfectly recorded by the aid of the Sphygmograph as to afford a means of diagnosis in cases of poisoning, or be the measure of the chances of the patient. It is at any rate certain, that by it we may determine the first moment at which the system feels the effect of the substance administered, whether it primarily affect the circulatory or the nervous system, or both, and ascertain by the determination of

predominance of pressure in arteries or veins, the possible effect of a remedy upon a condition of stasis in either.

The physiological and pathological indications in this direction are important and interesting, and the tracings, which have been taken with great care, are given in detail.

Four drugs have been selected for the experiments, of known purity and freshness, and in each instance with the exception to be noted, the first tracing was taken and the first dose of the drug also at 9 P. M., always at least $2\frac{1}{2}$ or 3 hours after the last meal of the day. The observations were made upon my own pulse, and as a comment upon the facility with which the instrument can be used, the tracings, in every instance, were made by myself.

The experiments with the first drug, *Cannabis Indica*, are given with minuteness of detail, as illustrative of the manner of making the observations, but the subsequent ones will be treated more briefly.

FIRST EXPERIMENT WITH CANNABIS INDICA.—ALCOHOLIC EXTRACT.

SPHYGMOGRAPHIC OBSERVATIONS.	PHYSIOLOGICAL EFFECTS.
OCTOBER 31st, 1872.	
9.15 P. M. First Tracing normal, smooth, and even (not recorded), 5 grains taken. . . .	9.15. Feeling vigorous and well.
9.35 P. M. (Tracing 181.) Two records, at 0° and 2½°. Diminished frequency. . . .	9.35. A feeling of lightness perceptible.
10 P. M. (Tracing 182.) Two records at 4½°. Oscillation singularly marked; tension increased; amplitude and frequency diminished.	10 P. M. Nervous and excited.
10.05 P. M. (Tracing 183.) Two records showing a sudden return of, or rather approach to, a normal condition.	10.05. Sudden freedom from any unusual feeling.
10.15 P. M., 7 grains more.	

FIRST EXPERIMENT WITH CANNABIS INDICA.—*Continued.*

SPHYGMOGRAPHIC OBSERVATIONS.	PHYSIOLOGICAL EFFECTS.
10.40 P. M. (Tracing 184.) Record at $2\frac{1}{2}^{\circ}$ shows capillary resistance and wave of recoil.	10.40. Excited.
11.45 P. M. (Tracing 185.) Two records at $2\frac{1}{2}^{\circ}$ and 0° , gave similar results, indicating venous impletion. Frequency increased.	
11.50 P. M. (Tracing 186.) Record at $2\frac{1}{2}^{\circ}$.	11.50. Drowsy and calm.
11.55 P. M. (Tracing 187.) Record at $2\frac{1}{2}^{\circ}$, both the latter exhibit impaired propulsive power of the heart.	
Total amount 12 grains within 2 hours.	

178

0

179

0

180

 $2\frac{1}{2}$

181

 $2\frac{1}{2}$

182

 $4\frac{1}{2}$

183

 $2\frac{1}{2}$

184

 $2\frac{1}{2}$

185

 $2\frac{1}{2}$

186

 $2\frac{1}{2}$

187

 $2\frac{1}{2}$

188

2

189

 $2\frac{1}{2}$

190

 $2\frac{1}{2}$

191

 $2\frac{1}{2}$

192

 $2\frac{1}{2}$

SECOND EXPERIMENT WITH CANNABIS INDICA.—TINCTURE.

INSTRUMENTAL OBSERVATIONS.	PHYSIOLOGICAL OBSERVATIONS.
<p>NOVEMBER 2d, 1872.</p> <p>9.15 P. M. Thirty drops.</p>	
<p>9.20, 9.25 and 9.45 P. M. (Tracing 188.) Records all taken at same pressure. At the latter hour the amplitude began to show increase of tension.</p>	<p>9.45 Beginning to feel an indefinable sensation of comfort.</p>
<p>9.45 P. M. Forty drops more.</p>	<p>10 P. M. Slightly exhilarated.</p>
<p>Tracings at 9.50, 10.00 (Tracing 189) and 10.15 P. M. (Tracing 190) exhibit only increase of tension with, at the latter hour, diminished frequency equal to ten beats.</p>	<p>10.15. Somewhat drowsy.</p>

SECOND EXPERIMENT WITH CANNABIS INDICA.—*Continued.*

INSTRUMENTAL OBSERVATIONS.	PHYSIOLOGICAL OBSERVATIONS.
10.20 and 10.25 P. M. (Tracing 191.) Tension and frequency variable.	10.25. All effects apparently gone.
10.25 P. M. Forty drops more.	
10.45 P. M. (Tracing 192.) Records exhibit great increase of arterial tension	10.45. Again exhilarated.
11 P. M. (Tracing 193.) Frequency greatly increased, equal to 30 beats and falling in five minutes as many; tension less.	
11.05 P. M. (Tracing 194.) Record shows increased cardiac excitement at beginning of systole, with some obstruction, either proximate or distal.	11 P. M. Drowsy, but not pleasantly so, nor as if from desire to sleep.
	Total amount 110 drops.

THIRD EXPERIMENT WITH CANNABIS INDICA.—TINCTURE IN LARGE DOSES.

INSTRUMENTAL OBSERVATIONS.	PHYSIOLOGICAL OBSERVATIONS.
November 5th, 1872.	
9 P. M. 100 drops. Tracing normal. . . .	9 P. M. Feeling well.
9.10 P. M. (Tracing 195.) Amplitude and therefore tension increased, frequency steadily diminishing till 9.45. Tracings at 9.30, 9.45. .	
10 P. M. 120 drops more.	10 P. M. No effect experienced.
10.10 P. M. (Tracing 196.) Diminished tension and the oscillation of cerebro-spinal implication. This tracing by accident in transfer, fails to show this except in the first wave. .	
10.15 P. M. Same.	

THIRD EXPERIMENT WITH CANNABIS INDICA.—*Continued.*

INSTRUMENTAL OBSERVATIONS.	PHYSIOLOGICAL OBSERVATIONS.
10.35 P. M. (Tracing 197.) Obstruction either proximate or remote.	
10.40 P. M. (Similar to tracing 195.) Diminishing obstruction.	
10.45 P. M. 200 drops more.	10.45. Very little effect.
11.15 P. M. (Tracing 198.) Diminished tension and evident sedation, but frequency slightly increased.	11.18. No effect whatever.
11.18 P. M. Same.	Total amount taken 420 drops!

FINAL EXPERIMENT WITH CANNABIS INDICA.—FRESH ALCOHOLIC EXTRACT.

INSTRUMENTAL OBSERVATIONS.	PHYSIOLOGICAL OBSERVATIONS.
November 9th, 1872.	
9.50 P. M. Twelve grains of fresh extract taken.	9.50 P. M. Feeling not well as usual
10 and 10.15 P. M. Tracings showed diminishing frequency and tension, and not feeling well a pressure of 0° was found to be the best for observation, instead of 2½° as heretofore.	owing to overwork; otherwise all right.
10.30 P. M. (Tracing 199.) Frequency still less, pulse small but normal, showing sedation.	10.15. A little nauseated, and eyes heavy.
	10.30. Feeling comfortable and well.

FINAL EXPERIMENT WITH CANNABIS INDICA.—*Continued.*

INSTRUMENTAL OBSERVATIONS.	PHYSIOLOGICAL OBSERVATIONS.
10.45 P. M. Pulse somewhat excited. Fourteen grains more taken.	10.45. Effect passing off.
11.25 and 11.40 P. M. (Tracings 200 and 201.) Records exhibited great weakness of cardiac power, it being difficult to obtain them even at 0°.	11.25. A few minutes exhilarated, then very drowsy, but no impairment of will.
11.45, 11.48 and 11.50 P. M. (Tracing 202.) The records taken showed a sudden decrease of frequency and tension and equally sudden increase.	11.45. Drowsiness gone, and feel free from any effect. 12.30 M. Terrific excitement, twitchings, dreams, &c., sensations as of swelling of the head, painful insomnia and feeling of desperate recklessness.

November 10th. (Tracings taken the day following the use of the drug.)	
7.50 A. M. Tracings small and showing weak heart.	7.50 A. M. Peculiar action of medicine still evident, head swollen, confusion of ideas, &c.
12.30 M. (Tracing 203.) Same, but showing also the slight dirotism of capillary dilatation.	12.30. Have been asleep and feel better; influence passing off.
Total amount taken 26 grains! Time, 2 hours and 40 minutes.	

SYNOPSIS OF EFFECTS OF THE REMEDY.

DOSE AND TIME—FIRST EXPERIMENT.	FIRST PERCEPTIBLE EFFECT IN TRACING, AND ITS CHARACTER.	MAXIMUM EFFECT.
5 grains, 9.15. . .	After 20 minutes, diminished frequency. . . .	<i>Maximum effect of first dose in 45 minutes.</i>
	After 45 minutes, marked cerebral disturbance, exhibited in oscillation and minimum amplitude and frequency, with increased tension.	
	In 50 minutes, sudden cessation of effect.	
	In 35 minutes, capillary disturbance and increased tension with increased frequency. . . .	
7 grains, 10.15. .	In 40 minutes, beginning of impairment of cardiac impulse, continuing two hours from administration of remedy.	<i>Of second dose in 30 minutes.</i>

SECOND EXPERIMENT.		
30 drops of Tr., 9.15 P. M. . . .	In 30 minutes increased tension. . . .	<i>Of tension in 35 minutes.</i>
40 drops more— 9.45. . . .	In 60 minutes from first dose, diminished frequency—arterial tension great. . . . In 1 hour and 10 minutes irregularity in tension and frequency, with increase in prominence of waves, showing cerebro-spinal stimulation. . .	<i>Of irritation in 35 minutes.</i>
40 drops more— 10.25. . . .	In 1 hour and 45 minutes great increase of frequency, equal to 30 beats; falling as many in five minutes more, with reduced tension. . .	<i>Of frequency in 1 hour 45 minutes.</i>
	In 1 hour and 50 minutes from first dose evidences of increased irritability of the heart, with some obstruction, either proximate or remote. . .	<i>Of diminished power 1 hour 5 minutes.</i> <i>Of some obstruction to circulation 1 hour 45 minutes.</i>

SYNOPSIS OF EFFECTS.—*Continued.*

DOSE AND TIME—FIRST EXPERIMENT.	FIRST PHYSIOLOGICAL EFFECT OF THE DRUG, AND ITS CHARACTER.	MAXIMUM EFFECT.
5 grs. 9.15. . .	In 20 minutes, lightness. In 45 minutes, nervousness and excitement. In 50 minutes, sudden freedom from any effect. In 25 minutes, excitement.	From first dose, maximum of excitement in 45 m. From second, maximum of excitement in 25 min.
7 grs. 10.15. . .	In 95 minutes, drowsiness and calm. . . .	Maximum of sedative effect in 12 minutes.
SECOND EXPERIMENT. 30 drops of Tr., 9.15 P.M. . . .	In 30 minutes, quiet.	Of exhilaration in this experiment 45 min. from 1st dose.

	In 45 minutes, exhilaration.	Maximum of drowsiness, in 1 hour.
	In 1 hour, drowsiness.	
40 drops more—	In 20 minutes after <i>second</i> dose, new excitement	Of exhilaration after second dose, in 20 minutes.
9.45.		
40 drops again at 10.25.	In 35 minutes, drowsiness.	Of drowsiness, in 35 minutes.

Synopsis of the two later experiments with *Cannabis Indica* need not be given. It may be briefly said of them, that the doses were large and repeated at nearly one hour intervals. The effect was in the first of these apparent in the tracing in ten minutes, and a steady diminution of frequency resulted, until in 45 minutes there occurred evidence of implication of the nervous system. In 35 minutes after the second dose there appeared evidence of some obstruction to circulation, either near the heart or in the capillaries, and after 420 drops had been taken the arterial tension was greatly reduced, with corresponding increase of the venous pressure, and marked sedation just two hours and fifteen minutes from the first dose, and thirty from the last and largest.

Finally sudden cessation of effect.

In the last experiment detailed, in which a fresh alcoholic extract was again used, the following facts were noticed :

1st.—Tracings abnormal from malaise at the beginning became normal in forty minutes, with marked sedation and diminished frequency. In fifty-five minutes began the stage of exhilaration, at which time a larger dose was taken. After fifty-five minutes the heart's impulsive power was evidently weakened, and shortly after began a vacillation both of equilibrium of pressure and frequency.

In one hour and forty-five minutes the nervous system was broken down by the excitement of reaction, a state lasting for twelve hours.

CHAPTER II.

EXPERIMENTS WITH GELSEMINUM.

It would be tedious and unnecessary to give the minute details of the experiments made with the remaining remedies.

In brief, these were *Gelseminum Sempervirens*, *Aconitum Napellus*, and *Quiniæ Sulphas*.

The first, the tracings illustrative of which are given (Nos. 204 to 209 inclusive), were with reference to the action of *Gelseminum Sempervirens* :

At 9.00 P. M. Six drops of Tilden's fluid extract were taken.

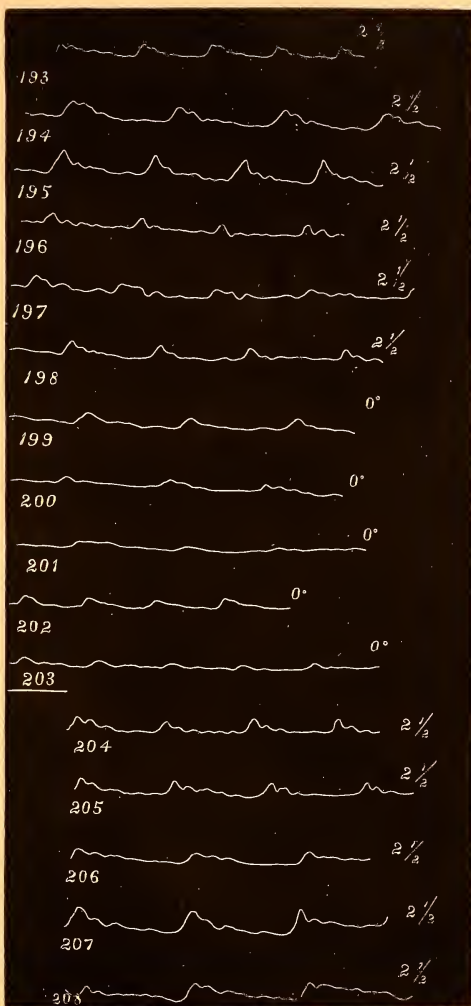
At 9.30 P. M. Being slightly drowsy, six drops more.

At 10.00 P. M. Ten drops more, with the following result:—10.15. A heavy feeling in the ears, and sense of weight over the forehead.

10.20 P. M. A peculiar sense of constriction at the base of the tongue.

10.40 P. M. Drowsiness increasing.

10.55 P. M. Peculiar slowness of respiration—7 to the minute.



11.05 P. M. Disappearance of all effects.

11.25 P. M. Sense of giddiness.

11.35 P. M. Free from all sensible effects.

This drug has been selected for experiment for the two-fold reason that difference of opinion as to its action has existed among medical men, and that a somewhat large personal experience with it enables me to speak of it with some familiarity. This experience has been favorable in puerperal eclampsia and the convulsive disorders of children, the neuralgic and congestive affections of the uterus or ovaries, and particularly in cardiac and pulmonary diseases, where sedation and reduction in frequency of pulse have been desired. With reference to its action in the latter respect, the tracings will be found instructive; and in view of the unfavorable opinion expressed by Da Costa (*Am. Jour. Med. Sc.* 1871) as to its action in irritable heart, they will probably be also interesting. In his hands, reduction of impulse and frequency were so slight as to be unimportant.

The tracings given may be compared profitably with those of Aconite, which succeed.

It is a fact worthy of notice, although already referred to, that in this case, as in many others, the Sphygmograph shows the action of the remedy often long prior to the exhibition of any sensible or physiological effect.

This, in the present instance, is made the more noticeable by the fact that at the beginning of the experiment the pulse was not perfectly normal, owing to fatigue, excitement, and loss of rest.

With regard to the dose used, a word is necessary. Having frequently observed the toxic action of the drug, even to ptosis, roaring in the ears, &c., after giving three drops of the fluid extract at intervals of half an hour, this fact of personal experience has been in mind throughout the experiment;—as with *Cannabis Indica* I was myself the subject in the case.

On the 12th of November, at 9 P. M., six drops were taken; at 9.30, six drops more; and at 10 o'clock, ten drops. The results, which were as follows, are also indicated on the chart.

Not being perfectly well, there existed either a recoil or dicrotic wave in the preliminary tracing, which in 30 minutes seemed rather to become more prominent, and but for the records that follow, might be at once set down as a true dicrotous wave. As at this time there will also be seen diminution of compressibility, as shown by diminished amplitude under the same pressure, the prominence of the waves, whatever its explanation, must be ascribed to a morbid condition, viz: that produced by the influence of the poison administered. The pulse at this interval has reached a minimum as to frequency, and in ten

minutes more shows slight impairment of rhythm. The new dose of ten drops exhibits its first influence in the tracing in 30 minutes, by increased arterial tension and nervous stimulation, followed however in five minutes by diminution of both, and great decrease in frequency. From this time on to the end of an hour, the tension in the arterial system slowly increased, although the frequency remained nearly the same, and after one hour and a half the appearance of some obstruction as shown in the flattening of the conjoined apices of the first and second events was manifest, and irregularity of impulse and of rhythm exhibited the effect of the poison upon the heart.

Neither of the effects last named could have been perceived by any other means than the Sphygmograph; and at this time the sensible action of the medicine had disappeared.

The simple deduction from this investigation, apart from what is already known of the remedy, lies in this—that while reducing the frequency of the pulse, it does so with an *increase of arterial tension*, and after a while impairment of the heart's action, indicating a toxic influence upon the nervous system.

It is therefore not surprising that singularly incompatible experiences have been recorded by different physicians.

CHAPTER III.

EXPERIMENTS WITH ACONITE.

The third experiment * was made November 14, 1872, with a fluid extract of Aconite root, upon a young lady perfectly well, as far as could be ascertained, and aged eighteen years.

A pressure of 2° was found the most available, and was, as in all these later investigations, maintained throughout: tension being ascertained by amplitude, as already described in the preceding pages. The oscillation evident in the first tracing was simply the result of nervous tremor.

This young lady took four drops in all, 1 at 1.50 P. M., one at 2.20, and two at 2.45. In twenty-five minutes from the first dose occurred the first effect in the tracing; reduction of frequency and force, there being no physiological influence perceptible. *In five minutes* more occurred a sudden increase of both, without apparent cause, although from the fact that the tracing shows slowness of collapse of the artery, it may have

* Tracings 209 to 213 inclusive.

arisen from capillary constriction due to the direct stimulus of the impelled current against them. In five minutes more this has disappeared, and in forty from the administration of the first dose, the force, frequency and arterial tension have reached a minimum without any perceptible physiological effect being experienced.

The new dose shows itself in twenty minutes instead of twenty-five, as with the first, and two drops additional were taken.

In thirty minutes thereafter, the pulse-writing being almost a straight line, and having thus exhibited the maximum effect of the remedy in a minimum of tension, force, frequency and complete disappearance of all evidences of nervous or other excitement, *the first appearance of any sensible effect occurred* in a simple dizziness upon exertion.

Aconite continued—larger doses.

The next experiment was made November 14, 1872, upon myself, with a fresh fluid extract of Aconite root, and its effects were briefly as follows (tracings 214 to 221 inclusive) :

The first effect visible in the tracing occurred in fourteen minutes, viz., diminished frequency ; and in three minutes more, or seventeen from the taking of

the remedy, a great increase of arterial tension, with prominence of the wave of recoil.

After thirty minutes this was slightly less, and the first physiological or sensible effect occurred in a sensation of fullness of the carotids.

The maximum of nervous excitement and increased tension is visible at 9.45, or 35 minutes after the dose, followed by reaction and minimum of frequency, and tension at 10.

With the next dose the *maximum*, showing the stage of excitement due to the remedy, occurs in thirty minutes. The reaction, or *minimum* of force, frequency and tension, and showing sedative influence, occurs ten minutes later. In fifty minutes a feeling of faintness occurred, not however indicated in the tracing, and therefore, probably, a reflex phenomenon due to the condition of the stomach.

In one hour and twenty minutes, when the true physiological effects of the remedy were shown, as stated on the chart, a great increase of frequency and arterial tension with cerebral excitement were manifest, followed however by reaction and variations in the pulse-wave, until at twelve o'clock the long even wave of health is given, even under a pressure of 5°, and all sensible effects had passed away.

The deduction from these experiments is of special interest, and we may compare it with a degree of cer-



tainty eminently satisfactory with that of Gelseminum.

Leaving out all other considerations, we have this one fact apparent, that Aconite unlike Gelseminum, while primarily showing a stage of excitement, yet reduces the heart's action as to frequency of beat *without increasing arterial tension*.

The application of this fact to pathology will be evident.

CHAPTER IV.

EXPERIMENTS WITH QUININE.

Two experiments with this drug are presented, showing the effects of single large doses, and of frequently-repeated smaller ones. The deductions, in brief, are as follows :

First. November 16th (tracings 222 to 225 inclusive). Being especially sensitive to the tonic action of quinine, and moreover very susceptible to the influence of substances having a bitter taste, when taken simply into the mouth, the first dose taken was but half a grain, dry, upon the tongue. Its action when thus administered cannot be mistaken as affecting the circulation ; a lessened frequency, increased tension, and developed vibratile character, were apparent in fifteen minutes, no sensible effects of course being manifest.

At this time, the pulse being 64 per minute, ten grains were taken.

The above-named features (tracing 226) were magnified, and reached a maximum in twenty-five minutes after the large dose, and in thirty minutes occurred the

minimum of tension, with, however, increased frequency, and after that a variation of both within a very brief interval.

The only inference from this experiment, relates to the stimulant and sedative properties of quinine upon the nervous and circulatory system.

Quinine continued—small and repeated doses.

November 18, 1872 (tracings 227 to 233 inclusive).

On this occasion two grains of the sulphate were taken every ten minutes up to sixteen grains, with the effects perceived in the tracings, beginning at 10 o'clock P. M. On this evening, as shown by the preliminary tracing, there existed the fatigue and slight excitement due to the arduous work of the day just closed.

At 10 P. M., first dose of two grains.

In seven minutes occurred diminished frequency. In twenty-three this had reached a maximum, the tension being slightly increased, as shown by the transmission of the alternate waves.

A sedative influence, both nervous and circulatory, became apparent at 11.30, and existed until 12 o'clock, when the influence upon the nervous system is shown by the peculiar shape of the primary wave and the delayed collapse of the artery (231).

From this hour, when a feeling of tension in the back

of the head was noticed, the excitement of the nervous system increased, and is thus described in my notes made the following day :

“Unsound and troubled sleep ; nervous jactitation and twitching ; stuffed sensation in the head, and frequent desire to micturate, with painful vesical spasm after each attempt—and heavy deposit of phosphates ; pain in the bowels ; and severe neuralgic or congestive pain under the left nipple, lasting all night.

“Awoke with all the sensations common to a man after a night of dissipation and excess. Feeling of twitching all over the body, with no apparent or actual trembling ; dull heaviness in the ears and back of the head, with pulse of 96.”

At 8.30 P. M. tracings were taken (232) which exhibited all the feelings above described as graphically as they were experienced.

The oscillation here evident furnishes an interesting comment to the rules relative to this feature, given on page 73.

The deductions from this experiment, aside from what is already familiar, in conjunction with the action of quinine, relate chiefly to the influence upon the frequency of the pulse and the state of the nervous system, the effect of large and small doses, and the moment at which their action begins.

Reference need not be made in this connection to the

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experiments with ordinary means of observation by others—detailed in the many periodicals of the day—as it is presumed that its singularly diversified actions under different circumstances are familiar, but the facility with which observation may be stamped as accurate or otherwise by the Sphygmographic record, is suggested by the examples here given.

CHAPTER V.

REMARKS IN CONCLUSION.

To attempt in any perfect manner to epitomize the indications afforded by the Sphygmograph in the numerous examples presented, would prove a serious task, especially as deeper meaning probably lies in the tracings than has yet been revealed ; but if the reader will bestow the requisite amount of patience upon their study the appearance of similarity will vanish, and assurance that both the pathological and physiological indications afforded by the instrument are of great importance, will seem well founded.

What we have endeavored to show, by the somewhat diffuse exposition of the subject, may, however, be thus briefly summed up.

First. That the new principle in the construction of the instrument exhibits a new and wider field as within its scope.

Second. The value of a knowledge of the minute peculiarities of the arterial current, in connection with the determination of the condition of both the vascular and nervous system.

(Under this head have been considered the condition of the heart as to vigor or irritability, character of impulse, duration of systole, hypertrophy eccentric or concentric, condition of the valves, etc. ; the relative tension in arteries or veins ; the condition of the former as to contractility, passive dilatation, degeneration, etc. ; and also the physiological inferences educed under the action of medicines.)

Third. *The power of the Sphygmograph to develope this knowledge*, and correctly record it.

(Under this have been considered the significance of each part of a tracing, so far as heretofore described, and also *new* features drawn from personal experience, substantiated by examples.

Studies of tracings and numerous cases have been presented, that the student desirous of forming his own conclusions may do so.)

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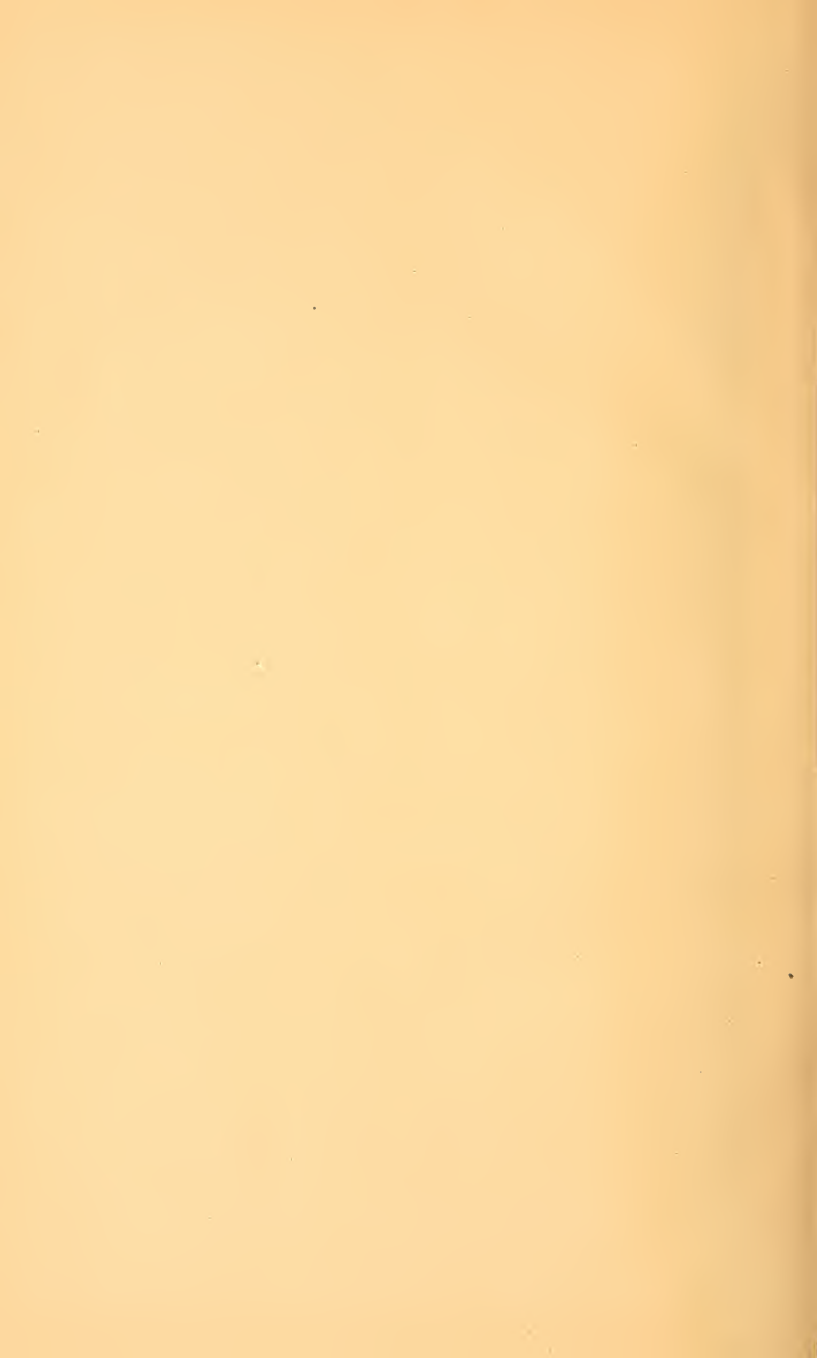
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